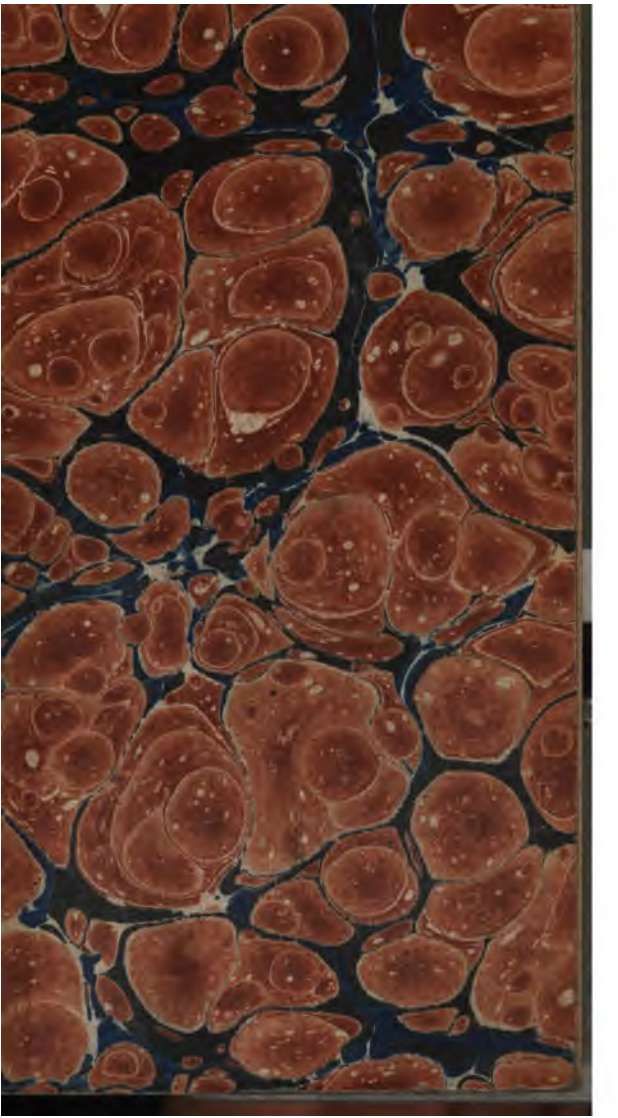
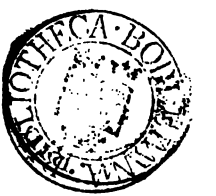


THE

ATMOSPHERE

AND

ATMOSPHERICAL PHENOMENA.



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THE ATMOSPHERE AND ATMOSPHERICAL PHENOMENA.

PART I.

THE NATURE, PROPERTIES, AND BENEFICIAL EFFECTS OF THE ATMOSPHERE IN THE SYSTEM OF NATURE, AND THE EVIDENCES WHICH ITS CONSTITUTION AFFORDS OF THE WISDOM AND BENEFICENCE OF THE CREATOR.

INTRODUCTION.

ALL the works of God, throughout the immensity of the universe, display the character, perfections, and agency of the Supreme Creator, to every rational and Christian mind that surveys them with attention and intelligence. From the magnificent luminaries of heaven to the comparatively small globe on which we dwell, and the smallest microscopic animalcule that glides through its waters, we perceive the impress of omnipotence and skill, which infinitely surpass all the puny labours and inventions of man. These works were evidently intended by their Divine Author to be investigated, contemplated, and admired by all his intelligent offspring, that their conceptions of

the Divine character may be expanded, and that they may be led to give unto Him "the glory due unto his name." The enlightened Christian, therefore, ought to devote a portion of his time and attention to the study and contemplation of the works of God, not only as a rational amusement, but as a solemn duty; for, in numerous passages in the sacred records, this duty is expressly inculcated: "Lift up your eyes on high, and behold who hath created these things"—"Stand still, and consider the wondrous works of God"—"The works of the Lord are great, sought out of all them that have pleasure therein"—"Great and marvellous are thy works, Lord God Almighty."

When we look around on the surface of the earth, and behold the beautiful and sublime landscapes which diversify its aspect, the variety of colours with which it is adorned, the myriads of trees, shrubs, and flowers which spring from its surface, and the rich perfumes they shed around them—the numerous animated beings which traverse the air, the ocean, and the earth, and the ample provision which is made for their subsistence and comfort—we can scarcely fail of being impressed with the conviction, that the Creator is a being of unbounded beneficence, that "His tender mercies are over all his works," and that the happiness of his sensitive and intelligent offspring is one great end of all his arrangements. When we consider the curious and exquisite structure of all the vegetable tribes, the numerous vessels with which

they are furnished, the thousands of delicate tubes, invisible to the naked eye, through which their sap and juices are continually flowing to the leaves and branches, the millions of pores through which they shed their delicious odours, and the curious contexture and the numerous beauties which the microscope alone can discover in their leaves, prickles, stamens, petals, and flowers:—when we consider the numerous orders of animated beings—the wonderful diversity of structure they exhibit, in their eyes, ears, feet, joints, claws, wings, and movements—the numberless contrivances which enter into their construction and functions—the thousands of adjustments, adaptations, borings, claspings, and polishings, which enter into the body of an animal a thousand times less than a mite—the adaptation of all these contrivances to the purposes of life, motion, and enjoyment, and their correspondence to the surrounding elements in which such creatures pass their existence:—and, in particular, when we contemplate the structure and functions of our own corporeal frames; the hundreds of bones of different shapes and sizes which support it; the hundreds of muscles of different conformation, which give motion to its different parts; the thousands of glands, secreting humours of various kinds from the blood; the thousands of lacteal and lymphatic tubes, absorbing and conveying nutriment to the circulating fluid; the millions of pores, through which the perspiration is continually flowing; the infinite ramification of nerves, diffusing

sensation throughout all the parts of this exquisite machine; and the numerous veins and arteries which convey the whole mass of blood through every part of the body ten times every hour:—when we consider these adaptations and arrangements throughout the vegetable and the animal kingdoms, we perceive the marks of a Divine intelligence and skill, which completely throw into the shade the most exquisite contrivances of human genius, and which convince us that the *wisdom* of the Creator is *infinite*, and "his ways past finding out."

In short, when we lift our eyes beyond the boundaries of the globe on which we dwell, and look upwards to that boundless firmament where suns unnumbered shine, and planets and comets run their ample rounds—when we behold ten thousand times ten thousand of luminous and opaque globes of vast dimensions, scattered in magnificent profusion throughout every region of infinite space; when we contemplate the sun occupying a space which would hold one million three hundred thousand worlds such as ours; and when we contemplate globes, fourteen hundred times larger than our world, flying through the voids of space with a velocity of thirty thousand miles an hour, and carrying along with them in their rapid career a retinue of surrounding worlds—we behold the effects of a Power which all the subordinate intelligences in the universe can never control, a power before which the mightiest achievements of human art sink into the same scale with the

flutterings of a microscopic animalcule; a power which astonishes and confounds the imagination, which sets at defiance human calculations, but which conveys to the mind a most impressive idea of the grandeur of the Divine Being, and of the magnificence of that universe which his hands have formed!

It is not merely in the scenes of the visible world that the attributes of Deity are conspicuously displayed. Even in the invisible regions of creation, which are impalpable to the organs of human vision, the perfections of the Eternal Mind are no less apparent to the philosophic and Christian inquirer, than in those external scenes of beauty and magnificence which arrest the attention of every spectator. Could we descend to the central regions of our globe, and contemplate the processes which are going on in those unexplored and unexplorable recesses; could we penetrate into the depths of the ocean, and survey the multiplicity of objects which lie concealed in its unfathomable caverns; could we ascend on the wings of the wind with the vapours which rise from its surface, and contemplate all the regions and transformations through which they pass, till they again descend in refreshing rains on the mountains and vales; could we wing our flight beyond the denser regions of the atmosphere into those places where fire-balls and shooting-stars have their origin, and where the aurora borealis displays its fantastic coruscations; could we ascend to the ethereal spaces which intervene between

us and the celestial bodies, and investigate those apparently empty regions which surround the atmospheres of all the planets; or, could we penetrate into the chemical processes and changes which are incessantly going on among the invisible atoms of matter, in the union and disunion of the different gases, in the various modifications of crystallization, in the circulation of the sap and juices in the minutest flowers, and in the internal vessels of microscopic animalcules; we should, doubtless, behold the operations of a Wisdom and Intelligence no less admirable and astonishing than what is displayed in the visible scenes of nature which are obvious to every eye.

Of those invisible regions of nature now alluded to, the ATMOSPHERE is one in which we are particularly interested, and which exhibits a striking scene of Divine wisdom and beneficence.

The term atmosphere may be defined to be "that body of air, vapours, electric fluid, and other substances which surrounds the earth to a certain height." This mass of fluid matter gravitates towards the earth, presses upon its surface with a certain force, revolves with it in its diurnal rotation, and is carried along with it in its course round the sun, at the rate of sixty-eight thousand miles an hour. This fluid mass is invisible to the corporeal organs; and hence, the great body of mankind are apt to imagine that the regions around us in which the birds *fly, and the* clouds move, are nothing else than

empty space; and, were it not that they sometimes hear its sound in the breeze, and feel its effects in the whirlwind and the storm, they would be disposed to deny that such a thing as the atmosphere had an existence. There is, however, no appendage to our globe which is so essentially requisite to the comfort, and even to the very existence of animated beings; for, were the earth and the ocean, the springs and the rivers, to remain as they now are, but were the hand of Omnipotence to detach from our globe the atmosphere with which it is now environed, it is absolutely certain that, in a few minutes, and after a few sighs and groans, all the eight hundred millions of men that now people the earth, and all the other animated beings that traverse the air, the waters, and the land, would sink into the slumbers of death, and disappear for ever from the living world.

In elucidating this subject, the observations that will be made may be arranged under the following heads:—

I. To prove that air exists, and that it is a material substance.

II. To consider its weight or gravity, and the force with which it presses on all bodies on the surface of the earth.

III. To exhibit several facts which the pressure of the atmosphere tends to illustrate.

IV. To illustrate the elasticity of the air, and the effects it produces.

V. To offer some considerations for illustrating the height of the atmosphere, or the

elevation above the surface of the earth.

VI. To illustrate its composition; or, the chemical principles of which common atmospherical air is composed.

VII. To illustrate its beneficial effects in the system of nature.

VIII. To exhibit the evidences which its constitution affords of the wisdom and benevolence of the Creator.

CHAPTER I.

Air is a material substance.

THE first inquiry, then, is, What is that air, of the importance of which we hear so much asserted? We *see* nothing, it may be said—we *feel* nothing. We feel ourselves at liberty to move about without any let or hindrance. Whence, then, the assertion that we are surrounded by a substance called air? A few facts and illustrations only will be sufficient to elucidate this position.

1. If we take a rod, and make it pass rapidly through what appears empty space, we shall hear a sound and feel a slight resistance, as if something had intervened to prevent the motion of the rod.

2. If we take a large fan, or an umbrella, when fully stretched, and push it forcibly from us, we shall feel a very considerable resistance, and a person opposite will feel a certain impression made upon his face, as if some substance had come in contact with it. Were we to take a very large umbrella—say from twelve to fifteen feet diameter—and stand on the top of a high

stair, or a building, twenty or thirty feet high, we might jump from such a position, while we hold it fully stretched, and gradually descend to the ground without violence or injury. It is on this principle that the instrument called a parachute is constructed, by means of which an aëronaut, while pursuing his aërial excursions, has left his balloon, when elevated nearly a mile above the surface of the earth, and descended in a few minutes to the ground, without shock or accident. Perhaps some contrivance of this kind might be useful to prevent accidents in the case of fires in large towns—when persons have attempted to jump from the windows of a third story to preserve themselves from being involved and destroyed in the burning mass. The circumstances now stated prove, that there is a certain material substance, though invisible, around us, which offers a sensible resistance to any body having a large surface when it is pushed rapidly through it.

3. That air is a material substance, appears from its excluding all other bodies from the place it occupies. Thus, if we take a glass jar, and plunge it with its mouth downwards into a vessel of water, only a very small quantity of water will get into the jar, because the air, of which the jar is full, keeps the water out; otherwise, if it were empty of every material substance, the water would rush in and completely fill the jar. Hence, we may learn why a vessel cannot be filled with water by plunging its orifice downward, and why a funnel, if its

pipe fit closely to the neck of a bottle, is not convenient for pouring off liquors; for, in order to put water or wine into a bottle, the air must pass between the neck of the bottle and the funnel to let the air out as the water rushes in. And hence, the practice in such cases, suggested by necessity, of pulling up the funnel a little when the liquor stops, in order to let the air rush out between the pipe and the neck of the bottle. It is on the principle now stated, that the diving bell is constructed, by which a person may descend to a considerable depth into the sea, and yet not be immersed in water, nor deprived of air for breathing.

4. If we take a smooth cylindrical tube shut at one end, and fit a plug or cork exactly to its open end, so as to slide along it, if the plug be so tight and soaked with grease, as to prevent all passage of any fluid by its sides, we shall find that no force whatever can push it to the bottom of the tube. There is, therefore, something within the tube, though invisible, which prevents the entry of the plug, and, therefore, possessing the characteristic of matter, and this something is air.

5. Let us take a pair of common bellows, and, after having opened them, if we shut up the nozzle and valve-hole, and try to bring the boards together, we shall find it impossible. There is something included that prevents this, in the same manner as if the bellows were filled with flax or wool; but, on opening the nozzle, we can easily shut them by expelling this

something that is within, which will issue with considerable force, and impel anything that lies in its way. This something can be nothing else than the air of the atmosphere.

6. The air, though for the most part invisible, may, in certain cases, be rendered an object of sight. If we take a telescope of high magnifying power, and, in the forenoon of a hot summer day, when the sun is shining, look through it to distant objects, we shall perceive the air undulating about the objects somewhat like the waves of the sea, and rendering them undefined and obscure. This is the principal reason why very high magnifying powers cannot be used, with effect, on telescopes for land objects, in the day time, when the sun produces undulations in the atmosphere; and the same cause frequently prevents distinct vision of celestial objects.

The above are clear proofs that the air, though not generally an object of sight, is, in reality, a material substance, as much so as water, wood, stones, or iron. This substance, in a state of rest, we call air; in a state of motion, we call it wind; and, in this state, its force is sometimes so great as to drive our wind-mills, impel our ships across the ocean, and even to overturn buildings, to tear up from their roots the largest trees, and to dash whole fleets to pieces of wreck.

CHAPTER II.

The weight and pressure of the atmosphere, and the quantity of matter it contains.

As air is demonstrated to be a body, like all other material substances, it must have weight, and the proportion its weight bears to other known substances is determined by experiment. If a bottle which contains about a quart be emptied of its air by means of an air-pump, or in any other way, and then accurately weighed in a nice balance, it will be found to be about sixteen grains lighter than it was before it was emptied of its air, which shows that a quart of air weighs sixteen grains. A quart of water weighs about 14,620 grains, or nearly two pounds. If this last number be divided by sixteen, the quotient will be nine hundred and thirteen, which shows that air is nine hundred and thirteen times lighter than water ; or, in other words, that it would require above nine hundred quart-bottles of air to weigh one quart-bottle of water. Other experiments which have been made to determine this point, lead to the result that, for every cubic foot of air, five hundred and twenty-three grains, or, one and one-fifth

ounce avoirdupois, are to be allowed; and, since a cubic foot of water weighs 1,000 ounces, the one divided by the other gives a result of eight hundred and thirty-three, the number of times that water is heavier than air. It is impossible to arrive at very great nicety in such estimates; but the general results of all the experiments which have been made on this point, lead to the conclusion that air is somewhere between eight hundred and nine hundred times lighter than water. These results, however, must be understood solely to apply to the air near the surface of the earth; for, as we ascend into the higher regions of the atmosphere, the air becomes gradually thinner and lighter, being less pressed with the air that is above.

We may now attend to the pressure which the atmosphere exerts upon the surface of the earth, and upon all bodies connected with it.

It has been proved by a variety of accurate experiments, that the atmosphere presses on every part of the earth's surface with a force, at an average, equal to about fifteen pounds on every square inch. This has been ascertained by what is called the Torricellian experiment. Take a glass tube about three feet long, open at one end, and hermetically sealed at the other: fill it with quicksilver, putting the finger upon the open end, turn that end downwards, and immerse it in a small vessel of quicksilver, without admitting any air, then take away the finger, and the quicksilver will remain suspended

in the tube about twenty-nine and a half inches above its surface in the vessel, sometimes more and sometimes less, according to the state of the atmosphere. It is evident, then, that the quicksilver is kept up in the tube to this elevation by the pressure of the atmosphere upon the surface of the mercury in the bason; for, if the bason and tube are put under a glass, and the air extracted, all the quicksilver in the tube will fall down into the bason; and, if the air be re-admitted, it will rise to the same height as before; or, if an opening be made in the top of the tube and the air admitted, the quicksilver will sink into the bason. The pressure, therefore, by the atmosphere on the earth, is the same as if a coating of quicksilver twenty-nine and a half inches thick were spread over every part of the earth's surface.

Now, it is proved that a square column of quicksilver twenty-nine and a half inches in height, and one inch thick, weighs just fifteen pounds, which counterpoise a column of air of the same thickness, extending to the top of the atmosphere; and, consequently, that air presses with this force upon every square inch of the earth's surface; and, of course, 2,160 pounds on every square foot, and 19,440 on every square yard. The experiment now described is, in fact, nothing else than the common barometer. The tube of the barometer is filled with quicksilver, or mercury; it then stands in a bason of quicksilver, is connected with a ball containing quicksilver, on the surface of which

the atmosphere presses, and, in most cases, stands at an elevation of about twenty-nine and a half inches, but subject to certain variations, according to the state of the atmosphere. When the weather is steady and serene, it rises to above thirty inches; when it is stormy and rainy, it frequently sinks to twenty-eight inches, or under, thus indicating the changes that take place in the weight of the air; and hence, it has obtained the name of the weather-glass.

Were the same experiment made with water, instead of mercury, a tube must be provided of about thirty-six feet long; and then it would be found, that the water in the tube would be supported by the atmospheric pressure to the height of thirty-two or thirty-three feet. This costly experiment, which has been seldom repeated, was first performed by the celebrated Pascal, at Rouen, in Normandy, in 1647. He exhibited the experiment both with water and with wine, in order to show the different heights to which these fluids would rise, according to their respective densities. He procured, at a glass-house, tubes of crystal glass forty feet long, which were fixed to the mast of a ship, that was contrived to be raised or depressed, as occasion required. He appointed a day for performing this experiment, and invited all the philosophers and others who doubted of the pressure of the atmosphere to attend, and to be witnesses of the wonderful nature of his experiment. The result was, according to the calculations he had previously made, that the

altitude of water in the tube was thirty-one and one-ninth Paris feet, equal to thirty-two feet two and a half inches English; and the altitude of the wine was somewhat greater, namely, thirty-one and two-thirds Paris feet, or thirty-two feet ten inches English; the wine, on account of its superior levity, rising about seven and a half inches higher than the water. He performed this experiment to convince the Aristotelian philosophers of those times of the folly of a notion which then prevailed, that the rise of the mercury in the Torricellian experiment and the rise of water in pumps were produced, not by the pressure of the atmosphere, but by an occult quality, which they denominated "Nature's abhorrence of a vacuum." They asserted that, in the upper part of the tube, deserted by the quicksilver, there were contained some *spirits*, evaporated from the quicksilver; which, being rarefied, filled up that space, thus assisting Nature, in a great emergency, against her mortal enemy, a vacuum. "Well, then, gentlemen," says Pascal, "take your own way. Here are two tubes, the one I am to fill with water, and the other with wine. You will all readily admit that there is a greater quantity of spirits in wine than in water; and, consequ ntly, that, if the empty space between the upper surface of the fluids and the top of the tube be filled with spirits, there will be a greater quantity of spirits in the upper part of the tube containing the wine, than in the tube containing the water; and, of course, the wine

will not rise so high as the water." To this they all readily assented. But, when the experiment was made, the wine was found to rise nearly eight inches higher than the water, as Pascal had previously calculated and predicted. This experiment was decisive; and, since that period, the figment of "Nature's abhorrence of a vacuum," along with many other absurdities, has been consigned to the slumber of the dark ages whence it originated.

A few years before the period now alluded to, the engineers of the grand duke of Florence, having received orders to raise a portion of water to the height of fifty or sixty feet, by means of a common pump, perceived, when they had made the attempt, that the pump refused its assistance, when the water was to be raised above thirty-two feet. They communicated the circumstance to Galileo, an eminent philosopher of that age, and asked him the reason of it. Galileo was not a little surprised, and was unprovided with an answer. He, however, put a good face on the affair, and gravely replied, that "Nature abhorred a vacuum only to the height of thirty-two feet." Torricelli, the disciple of Galileo, vexed at the water's refusing to ascend more than thirty-two feet in a tube void of air, made a new experiment with quicksilver, in the manner already described. He saw the quicksilver in the tube fall down, and leave an empty space at top, and remain suspended at the height of twenty-nine inches. "How," says *he,* "Nature abhors a vacuum only to the height

of thirty-two feet when it is water that ascends in a tube void of air, and only to twenty-nine inches when it is mercury! Vacuum does not frighten her beyond these measures! But why does she fear it to far more than twenty-nine inches when it is water that rises? Very likely this horror at vacuity is an idle fancy, a mere philosophical cant, which we take for good coin without understanding it." Reasoning in this way, and repeating a variety of similar experiments, he was, at length, led to the conclusion "that the diversity of the elevation of the two different fluids proceeded from the diversity of their weight, and that they were supported and counterpoised by a column of air, of the same diameter, reaching to the top of the atmosphere." Here the matter rests, and will rest throughout all succeeding generations.

This short sketch of the history of the experiments which relate to the pressure of the atmosphere will not be altogether out of place, if it has a tendency to guard us against the influence of preconceived notions, foolish prejudices, and of the authority of great names, which are some of the greatest obstructions to the expansion of the human mind, and the reception of useful knowledge. It was not before men began to emancipate themselves from such shackles that science commenced that brilliant career which has issued, in our times, in so many interesting and important discoveries. Similar prejudices are still prevalent in relation to the affairs of common life,

the facts of science, and the important truths of religion. We are only yet beginning to cast off the yoke of that ignorance, under the guise of wisdom, under which the men of other times bowed with such abject submission. Religious prejudices, in particular, derived from education and submission to mere authority, are frequently so strong that no species of reasoning, however convincing to an unbiased mind, is sufficient to subdue them. When certain dogmas or opinions, however futile, have got a firm hold on the mental faculties, all the arguments that can be derived from reason and philosophy, and even from the most cogent announcements of Divine revelation, are found altogether insufficient to displace them. And, as the fostering of erroneous opinions, in relation to religion, may endanger our best interests, both in relation to the life that now is and the life to come, it is of the utmost importance to all, and especially to young persons, that they examine, with care and without prejudice, every doctrine and opinion they embrace, without regard to human authority; founding all their views and sentiments on the dictates of enlightened reason, and the plain declarations of the word of God.

From what has been now stated, we may easily compute the weight sustained by the body of a middle-sized man, in consequence of the pressure of the atmosphere. Suppose the average stature of the human body to be about five feet nine inches; suppose the breadth in

front to be about one foot, and the breadth on each side half a foot; by allowing a little deduction for the narrowness of the head and feet, we may reckon about five feet in front, and five for the back part, and two and a half square feet for each side of the body, or fifteen square feet in all. It has already been stated that the atmospheric pressure on one square foot is 2,160 pounds. Multiply this sum by fifteen, the number of square feet on the surface of the human body, and the product will be 32,400 pounds, or somewhat more than fourteen tons, or the weight of more than fourteen ordinary cart-loads of heavy goods. This is the pressure sustained by every middle-sized man—a pressure which would be insupportable, and even crush us to pieces, were it not that it is equal in every part; pressing with the same force upwards, downwards, and on every side; and is, at the same time, counterbalanced by the spring of the air within us, which is diffused through the whole body, and re-acts with an equal force against the outward pressure. This pressure, however, is somewhat different at different times. When the air is lightest, the pressure is 31,150 pounds, and, when heaviest, about 33,660 pounds, making a difference of about 2,500 pounds, the weight with which we are compressed more at one time than at another. This great difference in the atmospheric pressure is found greatly to affect the animal functions and the state of health. A person labouring under an asthmatical com-

plaint will find his disorder increased when the air is light, as it has then less elasticity, and is not so capable of expanding the lungs. The air is generally lightest in hazy and rainy weather, when the clouds descend, and the mists cover the mountain tops. Every one then feels the effect, by a certain degree of lassitude and depression of spirits, occasioned by the surrounding gloom, and by being deprived of an atmospheric pressure amounting to more than 2,000 pounds. The fibres of the body are relaxed, the contractile force of the muscles diminished, and a languid circulation of the fluids ensues, which sometimes produce obstructions, fevers, and headaches; and, in most persons, a sort of indolence and gloomy inactivity. Whereas, when the air is heavy, and the clouds ascend to the higher regions, and appear like fine fleeces on the blue vault of heaven, the nerves and fibres of the animal system are braced by the additional pressure of the atmosphere, the blood-vessels exert their full power, the solids are compressed, the fluids circulate with increased vigour, we feel light and alert, and the elevation of the animal spirits is increased by the splendour and activity of the surrounding scene.

Weight of the whole atmosphere.—From the facts now stated, we may form an estimate of the weight of the whole body of the atmosphere which surrounds the surface of the earth. The surface of the globe contains, in round numbers, 200,000,000 of square miles; every

square mile contains 27,878,400 square feet; and these two numbers multiplied together, produce 5,575,680,000,000,000; or, five thousand five hundred and seventy-five billions, six hundred and eighty thousand millions, equal to the number of square feet on the surface of the earth; which, multiplied by 2,160 pounds, (equal to the pressure on every square foot,) produces the sum of 12,043,468,800,000,000,000; that is, twelve trillions, forty-three thousand four hundred and sixty-eight billions, and eight hundred thousand millions; which is equal to the number of pounds which constitute the weight of the whole atmosphere, or 5,000,000,000,000,000; that is, about five thousand billions of tons. A more definite idea of this weight may be obtained by supposing a ball of lead, extending from London to Oxford, stretching sixty miles perpendicularly above us, and in every direction; or, in other words, a ball of lead one hundred and ninety miles in circumference, and about sixty miles in diameter. Suppose this ball placed on one end of an immense balance, and the whole atmosphere on the other, they would nearly counterpoise each other. So that this invisible fluid, which we are apt to consider as almost a nonentity, when considered as a whole, contains a weight which it is difficult for numbers to express.

It need only be observed further on this point, that the air decreases in density in proportion as we ascend to the higher regions of

the atmosphere. At the height of seven miles, the air is four times rarer than at the surface of the earth; at the height of fourteen miles, it is sixteen times rarer; at the height of twenty-eight miles, it is two hundred and fifty-six times rarer; at the height of ninety-six miles, it is 268,435,456 times rarer; and, at the height of five hundred miles, it has been computed, that a cubic inch of such air as we breathe at the surface of the earth, would be so much rarefied, that it would fill a hollow sphere equal in diameter to the orbit of the planet Saturn, which is 1,800,000,000 of miles in diameter. This is a necessary consequence of the elasticity of the air, and of its want of compression in the higher regions; and that this is in reality the case, is proved by experiment as well as by calculation. When we take a barometer to the top of a mountain only half a mile in perpendicular elevation, the mercury falls from thirty to twenty-seven inches; and the fall of the mercury is in proportion the higher we ascend. Those travellers who have climbed to the tops of lofty mountains know, by experience, that the air is much thinner in those regions than in the plains below. Their breathing becomes difficult and painful, their hands and feet swell, and they are sometimes seized with a vomiting of blood. They also find, that the atmosphere becomes clearer as they ascend, and is unable to support the clouds. We are informed by Don Ulloa that, while he stood on the top of the Andes, in

Peru, "the clouds, which were gathered below the mountain's brow, appeared like a tempestuous ocean, all dashing and foaming, while the lightnings were breaking through the waves, and the thunders rolling beneath his feet, far below the spot on which he stood. In the mean time he enjoyed a serene and cloudless sky, and left the war of the elements to the unphilosophical mortals on the plains below."

Those who have taken a flight to the higher regions of the atmosphere in balloons, have beheld scenes of a similar kind. Mr. Baldwin, who ascended in a balloon from Chester, in 1785, relates that, at a certain elevation, the earth was entirely hid from his view by an immense mass of vapours, which he compares to a sea of cotton, tufted here and there by the action of the air, and, soon after, the whole became an extended pavement of white cloud. The reason of all this is obvious: the clouds are vapour, or water rarefied by heat. Vapour is lighter than air near the surface of the earth, and, consequently, ascends in it; but, in the higher regions, the air is thinner and lighter than these vapours, and, of course, is unable to support them beyond a limited height; which circumstance undeniably proves that the air is lighter the higher we ascend.

The pressure of the atmosphere may now be illustrated by a few simple experiments. The instrument called the air-pump affords, on the whole, the best means of illustrating the pressure of the atmosphere. This instrument

bears a certain resemblance, in its principle and action, to the common house-pump. It consists of a hollow cylinder or tube, in which a piston is alternately raised and depressed by means of an iron rod attached to the handle of the pump. In the piston there is a valve, which opens by any pressure from below, and is shut by any superincumbent pressure, like the flapper of a pair of bellows. When the piston is forced down, the valve is opened from below by the pressure of air, or whatever fluid the pump may contain. The fluid then gets above the valve, and is lifted up by the raising of the piston, and carried out of the pump, the valve being then shut by the pressure of the air above it. At the top, is a metal plate ground to a perfect plane surface, on which is placed an inverted glass jar or receiver, whence the air is to be extracted. A hole in the plate is connected with a tube which communicates with the pump-barrels. By working the handle of the instrument for some time, the receiver will soon be nearly exhausted of all the air it contains, and the effects produced in a vacuum, or place void of air, may then be exhibited. The following, among other experiments, may be shown by the air-pump. If the receiver be open at both ends, and the upper orifice be stopped by the hand, when the air is exhausted, the pressure of the external air will be such as to prevent the removal of the hand, and will cause a certain degree of pain. If a piece of bladder be tied tightly over

the orifice, as the exhaustion proceeds, the bladder will be pressed inwards, and will finally burst with a loud noise. In the same manner, if a flat piece of window-glass be placed upon the orifice, when the air is exhausted, the glass will be broken into a number of pieces by the external pressure of the atmosphere.

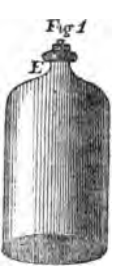
But as comparatively few persons have an opportunity of performing experiments with the air-pump, a few simple experiments, equally convincing, which every person has it in his power to perform, may here be described.

1. Take a wine or an ale-glass, and fill it with water; take a smooth piece of writing paper, and press it firmly against the edges of the glass, so that no air get in between the paper and the water, then turn the glass upside down, and the water will be supported by the pressure of the atmosphere upon the paper. That it is the external pressure of the atmosphere upon the paper which supports the water will appear, when we consider that the paper, instead of being convex, by the pressure of the water downwards, is concave, by the pressure of the air upwards. If a lighted candle be placed under the paper, with its flame touching the paper, we may hold it for an indefinite length of time, without its producing any effect upon the paper, or setting fire to it.

2. Take a wine-glass, and burn a piece of paper in it, and, while the paper is burning, if we place the palm of our hand firmly upon the edges of the glass, the glass will stick fast

to the hand, producing a certain degree of pain, and it will require a considerable degree of force before the hand can be detached from the glass. In this experiment, the burning of the paper rarefies the air, and nearly expels it from the glass, and then the atmosphere presses with its whole weight upon the hand.

3. Take a glass tube, two or three feet long, of a narrow bore; plunge one end of it in a bason of water; apply the mouth to the other end, and draw out the air by suction; the water will instantly rise into the tube by the pressure of the atmosphere on the water in the bason; and, if we immediately place our thumb firmly on the upper part of the tube, and withdraw it from the water in the bason, the water will be suspended in the tube by the pressure of the atmosphere, although the tube is open below; but, when the thumb is removed from the upper part of the tube, the water in it will run out, in consequence of the pressure of the atmosphere from above.



4. Take a tin vessel, six or eight inches long, and about three in diameter, with its mouth

about a quarter of an inch wide, as E F (fig. 1.) Pierce a number of small holes in its bottom, about the diameter of a common sewing-needle. Plunge this vessel in water, and, when full, cork it up, so that no air can enter at the top. While it remains corked, no water will run out, being prevented by the atmospheric pressure upon the bottom of the vessel; but the moment it is uncorked, the water will issue from the small holes by the pressure of the air from above. The same experiment may be made with a tin-plate tube, about an inch in diameter, open at the top, and having its bottom pierced with a small hole. When filled with water and tightly corked at the top, it may be carried for miles without losing a drop of water, notwithstanding the hole in the bottom.

5. In order to show the lateral pressure of the atmosphere, take a tube, as G H, (fig. 2,) six or seven inches long, having a small hole on each side, as I K. When filled with water, and tightly corked, no water will run out from the sides of the tube, but the moment the cork is taken out, the water will run out at I and K, as represented in the figure.

6. Take a wine-glass and burn in it a piece of paper; then invert the glass, while the paper is burning, over a saucer full of water, the water will rush up into the wine-glass, in consequence of the air being rarefied or driven out by the burning paper, and in consequence of the pressure of the atmosphere upon the surface of the water in the saucer.

These experiments show that the atmosphere presses in all directions, upwards, downwards, and laterally. This subject has been dwelt on somewhat particularly, because the atmospheric pressure forms an important element, and a mechanical power in the construction of steam-engines, atmospheric railways, and other modern inventions, which are now of such great utility in propelling carriages along railways, and steam-vessels across seas and oceans.

CHAPTER III.

Facts illustrated by the pressure of the atmosphere.

Let us now attend to a few facts which the pressure of the air tends to explain and illustrate.

1. The atmospheric pressure explains the nature of the process vulgarly termed suction. When we attempt to take a draught of water out of a bason, or a running stream, it is commonly said that we draw in the water by suction; whereas the fact is, that instead of drawing the water into the stomach, we only draw the air into the lungs, and the atmosphere performs the other part of the operation. The process is simply this:—We immerse our lips into the water, so as to prevent the entrance of air into the mouth; we then make a vacuum in the mouth by drawing the air into the lungs, after which the pressure of the atmosphere upon the surface of the water forces it upwards into the mouth. That such is the process of receiving a draught of water when the mouth is held downwards, appears from this circum-

stance, that if the lips do not *touch* the water, we might draw in the air by what is called suction for twenty years, and not receive a single drop into the mouth.

The same principle explains the action of a child sucking the breast of its nurse. The operation of cupping is performed in the same way. In this case, the operator takes a small glass, close at the top, and holding it for some time over the flame of a candle, or lamp, the air is thereby rarefied, and part of it drawn out. The glass is then suddenly placed on the part of the body to be cupped, and adheres to the flesh by the external pressure of the air. The flesh rises in the glass, and the blood and serosities are forced from the wounded vessels into the glass by the atmospheric pressure on the parts around.

2. It is owing to the atmospheric pressure that two polished surfaces, which accurately fit each other, adhere with great force. This fact is well known to glass-grinders and polishers of marble. A large lens, when ground very smooth, requires more than the strength of a single individual to pull it directly from the tool. If the surface is only a square inch, it will require fifteen pounds to separate them perpendicularly, though a very moderate force will make them slip along each other. Were the surface six inches square, the force requisite to separate the two pieces would be equal to five hundred and forty pounds. But this cohesion is not observed, unless the surfaces are

wetted or smeared with oil or grease, otherwise the air gets between them, and they separate without any trouble. That this cohesion is owing to the atmospheric pressure, is evident from the ease with which the plates may be separated in an exhausted receiver by means of the air-pump. The same cause contributes in a powerful degree to give effect to the cohesion of bodies by means of mortar and cements. When two pieces of wood are to be glued together, their surfaces are first made as smooth as possible; a glutinous substance is then applied to fill up all the pores and inequalities; they are then pressed together, which prevents the air from insinuating itself between them, and the external air then presses upon them with a force of fifteen pounds on every square inch. There can be no question that the stability of our houses and garden walls depends, at least in a great measure, upon the same principles; for the more completely every crevice between the bricks or stones is shut up, by means of mortars and cements, from the insinuation of the external air, the more firm and stable is the building.

To the same cause is to be attributed the action of a boy's sucker in lifting large stones from the ground. The sucker is made of stiff wetted leather fastened to a string; the moisture upon the leather, when it is pressed down upon the stone, prevents the air from getting in between the leather and the stone, and if the sucker be four inches square, it will require a

force of two hundred and forty pounds to separate it from the stone. In certain cases, such contrivances, on a large scale, might be sometimes useful as a mechanical power.

3. Another circumstance which is accounted for on this principle is, the strong adhesion of snails, periwinkles, limpets, and other molluscous animals, to the rocks on which they are found. The animal forms the rim of its shell so as to fit the shape of the rock on which it intends to cling. It then fills its shell either with its own body or with water. In this condition, it is evident, that we must act with a force equal to fifteen pounds on a square-inch before we can detach it from the rock. This may be illustrated by filling a drinking-glass to the brim with water, and, having covered it with a piece of thin wet leather, place it upon a table, and it will be found to require a very considerable force to pull it straight upward. But, if we place a snail adhering to a stone in an exhausted receiver, it will drop off by its own weight. It is owing to the same cause that bivalve mollusca, such as *oysters* and *mussels*, keep their shells so firmly shut, and require such a degree of force to open them. But, if we grind off a bit of the convex shell, so as to make a small hole in it, the air gets in, and it opens with the greatest ease. The same thing takes place when it is put under the exhausted receiver of an air-pump. It has been lately discovered that it is owing to the same principle that flies and other animals

have the power of walking on a perpendicular pane of glass, or on the ceiling of a room, with their backs downward. This has been proved to arise from a power they possess of squeezing out the air between the inside of their feet and the surface on which they tread, and thus being supported against the outside of their feet by the pressure of the atmosphere.

4. It is owing, in a great measure, to the pressure of the atmosphere, that frosts occasion a scantiness of water in our fountains and wells. This is not caused, as is generally supposed, by the freezing of the water in the bowels of the earth. The most intense frost of a Siberian winter would not freeze the ground two feet deep, but a moderate frost will consolidate the whole surface of a country, and make it impervious to the air, especially if the frost has been preceded by rain, which has soaked the surface. When this happens, the water which was filtering through the ground is all arrested, and kept suspended in its capillary tubes by the pressure of the air, in the same manner as water is suspended in a tube which is closed at one end, as in the third experiment stated in the preceding chapter (p. 34.) A thaw melts the superficial ice, and allows the water to run out in the same manner as it does when the thumb, in that experiment, is removed from the top of the tube.

5. It is well known that a cask full of water, or spirits, will not run by the cock, unless a hole be opened in the top, or some other part

of the cask. The reason is, that the air presses upon the opening in the cock, and prevents the liquor from flowing; whereas, when an opening is made at the top, the pressure of the air from above forces it down. If, indeed, the hole in the cask is of large dimensions, it will run without any other hole, because air will get in at the upper side of the hole, while the liquor runs out by the lower part of it. For the same reason, a small hole is made in the lid of a tea-pot to insure its pouring out the tea, otherwise, when the tea-pot is quite full, it would be difficult to make the tea run out at the spout, the pressure of the air from below tending to prevent it.

On the same principle depends the performance of an instrument used by spirit dealers, for taking out a sample of their spirits. It consists of a long tin-plate tube, AB, fig. 3, open at top at A, and ending in a small hole at B. The end B is dipped into the spirits, which rise into the tube; then the thumb is clapped on the mouth A, and the whole is lifted out of the cask. The spirit remains in it till the thumb be taken off; it is then allowed to run into a glass for examination. We are informed by certain travellers, that some of the rude tribes of Asia and Africa, with whom they have travelled, have a similar method of acquiring a draught of water, though they do not understand the

Fig. 3.

principle on which it depends. They provide themselves, in their journeys, with a long hollow cane, and, when they wish to drink, or to give their companions a draught of water from a stream or pool, they place the hollow cane in the water, and apply their mouth to the upper end, and draw out the air, when the water rushes in and fills the interior of the cane; they then apply their thumb to the upper end, take the cane out of the water, and apply it to the lips of their thirsty companion, when the water rushes into his mouth. This mode of taking a draught of water may, in some cases, be very convenient when we cannot easily apply our lips to the surface of a running stream.

The action of the syphon depends on the same principle. A syphon is a bent tube, the one end of which is longer than the other, as AB, fig. 4. If the tube be filled with water, and the shorter leg be placed in a vessel of water, E, immediately upon withdrawing the finger from the longer leg, the water will flow out till all the liquid in the vessel is emptied. By means of this instrument, we can convey water from a cistern over a rising ground, provided its perpendicular elevation above the level of the fountain does not exceed thirty-two feet, and that the leg, from which the water runs

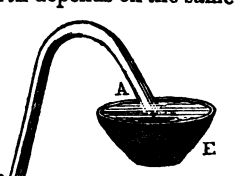


Fig. 4.

off, is *below* the level of the cistern; because the weight of a column of water, about thirty-two or thirty-three feet high, is equal to the weight of a column of air reaching from the surface of the earth to the top of the atmosphere. The pressure of the atmosphere upon the water of the vessel, or cistern, produces this effect.

It might be shown, that the common pump for raising water, the fire-engine, the steam-engine, the forcing-pump, and many other pneumatic and hydraulic engines, derive their power and utility chiefly from that extensive and universal agent—the pressure of the atmosphere; without the assistance of which many of our most powerful engines would be arrested in their operations, and sink into feebleness and insignificancy. But this chapter shall be concluded by a few general remarks, suggested by this subject.

The discovery of the pressure of the atmosphere, and of its agency in the system of nature, formed a new era in the history of science. However common it is now to perform the Torricellian experiment, and to talk about the pressure of the atmosphere, it was a subject which, less than two centuries ago, struck with astonishment all the learned throughout Europe. So wonderful and incredible did it at first appear, that it was not till after the lapse of several years—till after opinions which had prevailed for ages had been overturned, and the most decisive experiments had been *performed, in* every possible way, that it was cor-

dially received. And, indeed, when we consider the effects of this powerful agent, in the numerous operations both of nature and art, there is something which tends to excite our admiration more than all the fairy tales which the human fancy has created. We behold its operation in compressing the bodies of all animated beings—in counterpoising the internal pressure of the circulating fluids, and preventing the elastic force of the internal air from bursting the arteries and veins. We behold its operation in forcing-pumps and fire-engines —in raising water from deep pits, and carrying it to the tops of the highest buildings—in giving motion to our spinning-machines, and in propelling large vessels along seas and rivers—in the action of Hiero's fountain, of syphons and barometers; and in many other cases where its agency could scarcely have been suspected. What can be more unlike than the working of a fire-engine, when spouting a column of water to the top of a building in flames, and the crawling of a fly upon a window-pane, or the ceiling of a room? Yet both these operations are performed by the same means, the pressure of the atmosphere.

But what appears no less striking than such operations, is, the pressure of the atmosphere upon our own bodies. It has already been stated, that this pressure amounts to above thirty thousand pounds. Were the half of this weight to fall on one side of our bodies, without being counteracted by any other power, it

would produce an effect similar to that of a heavy wall, or the roof of a house falling flat upon us, and would infallibly drive the breath from our lungs, and crush to pieces every bone. What is it, then, which prevents such a terrible effect? A small quantity of air within us, which would not weigh above a single ounce, by its strong elastic force, counterpoises the effects of this tremendous pressure; so that, instead of lying as a mountain on our loins, it acts like wings to our feet, or like sinews to our limbs. When a flat bottle is empty, and laid on its side, we might imagine that the weight of the air would break it to pieces; but the air which is contained within the bottle, whether stopped or not, has the same power by its elasticity, to prevent its breaking, as the air without has to crush it to atoms. But, if we apply a syringe to the neck of such a flat bottle, and exhaust the air which is inclosed within, the extraction of that small body of air, which, by its elastic spring, supported the sides of it, gives room to the external air to act on the surface of the bottle with all its force, and the bottle will fly into a thousand pieces. Such would be the case with respect to our own bodies, if an exact balance were not kept up between the pressure of the atmosphere without, and the elastic force of the air within; and, in this instance, as well as in a thousand other instances, we have a striking evidence both of the wisdom and the benevolence of Him who at first created and arranged all the

powers and elements of nature, so as to render them subservient to the preservation and comfort of every species of animated existence.

It is owing to the same admirable arrangement of the Creator, that our dwellings are not crushed to atoms. Suppose an apartment only twelve feet square, and nine feet high, the pressure of the air upon the four sides, and the roof, containing five hundred and seventy-six square feet, is equal to one million, two hundred and forty-four thousand, one hundred and sixty pounds! This enormous pressure is balanced by the resistance of the small quantity of the air in the room, which weighs only ninety-seven pounds; so that, here is a small weight of ninety-seven pounds, counteracting a pressure of 1,244,160 pounds! Without this wonderful balance, no house could be habitable, no creature could remain alive; our glass windows would be shattered to atoms; an army-tent, a peasant's house, or a shepherd's hut, yea, even our most stately edifices, would be crushed to atoms.

It appears, then, that we are immersed in an invisible fluid, which, on the one hand, by its enormous pressure, threatens to crush us to the earth, and, on the other, by its elastic force, to burst our blood-vessels, and tear our whole frame to pieces. The equality or equipoise of these two formidable and death-menacing powers, is our only safeguard and defence; and shows us how "fearfully and wonderfully" we are every moment preserved by that Almighty

Being, "in whose hand our breath is, and whose are all our ways." Here we have a striking evidence of his benevolence and skill, in having, by his wisdom, reconciled and balanced two such formidable and contending powers, and so tempered them, that the impetuosity of the one is checked by the activity of the other; and all nature, instead of being shattered and destroyed, is preserved in safe and harmonious order. Were it his design to destroy the inhabitants of our world, or to render them miserable, we see how easily this could be effected. He has only to permit one of those powers now described to act without control, and the work of destruction is at once accomplished. So that in his "hand is the soul of every living thing, and the breath of all mankind." He upholdeth our souls in life, and his merciful visitation sustains our spirits. It is the province of true philosophy to trace the attributes of the Almighty, in every part of his operations, in the system of nature; and there is no scene throughout the universe, where his voice is not heard, and where his power and wisdom are not conspicuously displayed to those who have ears to hear, and eyes to see, and spiritual discernment to recognise the footsteps and the agency of an almighty, though invisible, Intelligence; "for in him we live, and move, and have our being."

CHAPTER IV.

The elasticity of the air, and the phenomena it explains.

THE atmosphere is that ocean of air which surrounds our globe on all sides, and in which we live and breathe. We are plunged into the bottom of this vast aërial sea, as the fishes are plunged into the depths of the ocean. Before we were brought into the world, we were furnished with a diaphragm and lungs, with cartilages, ribs, and muscles, to enable us to draw in this vital fluid. The first rush of the air into the lungs, and the cries which accompany it, announce life and sensation. More than a hundred muscles are employed in drawing in and expelling this aërial fluid; and this operation is continued, without intermission, till death. In this element we pass the whole of our existence, from the cradle to the grave; it surrounds us wherever we go, whether on sea or land, and almost all our enjoyments depend on its benign agencies. This element, however, is impalpable to our senses. By its transparency, it escapes our ocular inspection; by its thinness, it eludes our grasp; it cannot be perceived by our smell or taste, nor even by

our organs of hearing, unless when it is in a state of tremor and agitation. But we are fully assured, in numerous instances, that the powers of nature may be in complete existence, though they are imperceptible to every organ of sensation; and hence we ought to guard against an error common both to the vulgar and to philosophers, that "the things which we cannot see, have no real existence." The atmosphere, though invisible, is one of the most important and essential constituents of our terrestrial habitation. We could live for a few days without food, or drink, or sleep; we could pass weeks and months without the light of the sun, or the glimmering of a star; but if we are deprived only for a few minutes of the vital air, the lungs refuse to play, the heart ceases to beat, the blood stagnates in the arteries and veins; we faint, we sicken, and die. The powers of the animal machine are broken; the thoughts and perceptions vanish; the dust returns to its kindred dust, and the spirit returns to God who gave it.

We shall now chiefly attend to the illustration of the elasticity of the atmosphere. By the elasticity of the air, is meant that property by which it contracts itself into less space, when an additional pressure is laid upon it, and by which it recovers its former dimensions when the pressure is removed. When I take a piece of whalebone, or a watch-spring, and bring the two ends together, as soon as the force thus employed is removed, the spring

returns to its former position. In such cases, we say that the body is elastic. When I take a small quantity of wool into my hand, and compress it, upon opening my hand, it recovers its former bulk, by the natural spring of its fibres; and hence we conclude that this substance possesses a certain degree of elasticity. In like manner, if I take a bladder and fill it with air, and apply a force to the sides of it, so as to compress it into a smaller space, when the force is removed it immediately expands, and fills the same space as before, which clearly proves that the air contained in the bladder is of an elastic nature.

In consequence of this elastic property, the air always endeavours to expand itself, and to occupy more space. This is proved by taking a bladder, containing only a small quantity of air, tying its neck close, so as to prevent the escape of the air, and then placing it under the receiver of an air-pump. So long as the bladder is exposed to the pressure of the atmosphere, it will remain in the same state; but, when the air is exhausted from the receiver, and the external pressure removed, the side of the bladder, which was flabby and lax, stretches itself out, swells, and becomes tight, being raised by the elastic power. And, if the air be again let into the receiver, the bladder returns to its former shape. By a similar experiment it is shown, that the expansive power of the small quantity of air in the bladder is capable of raising leaden weights of

a considerable size. In consequence of this strong elastic power of the air, a person, by blowing into a pipe connected with several bladders, has been able sensibly to raise a mill-stone, which was placed upon the bladders; which demonstrates the very strong expansive power of a very small quantity of air.

On the same principle, were a bladder, containing a very small quantity of air, taken to the higher regions of the atmosphere, it would gradually expand the higher it was carried, in consequence of the pressure of the atmosphere being gradually diminished, till, at length, it would burst the bladder, by the expansive force with which it is endued. In like manner, heat increases the elasticity of air. If a bladder, containing a small quantity of air, be placed before a strong fire, the small portion of air it contains will expand, till the bladder appears quite full, and ready to burst. There is another striking experiment which demonstrates this elastic force of the air. When a thin bottle with flat sides is firmly corked, so as to prevent the included air from escaping, is placed under the receiver of an air-pump, and the air exhausted, the spring of the air within it will dilate with so much violence, as to break the bottle to pieces. In like manner, were the pressure of the external air completely removed from our bodies, and the escape of the internal air prevented, the elastic force of the air within us would immediately tear the lungs and other vessels to pieces, force the blood through the

arteries and veins, and put an end to all the functions of the animal machine. If an animal, as a cat, mouse, or bird, be put under a receiver, and the air exhausted, the animal will be at first oppressed as with a great weight, then grow convulsed, their bodies will swell, and if they are allowed to remain only for a few minutes, they inevitably die. Were we to take a shrivelled apple, and put it under the receiver of the air-pump, and exhaust the air, the skin will gradually swell as the pressure of the air diminishes, the wrinkles will be filled up, and the apple will appear as if fresh-gathered. When the air is let in, it returns again to its former withered state. The effect now stated, is owing to the elasticity of the air in the inside of the apple, which expands when the atmospheric pressure is removed.

From a variety of experiments it is demonstrated, that the spring of the air is equal to its weight, and produces the same effects as its pressure; for, action being equal to re-action, the force which the elasticity of the air exerts, in endeavouring to expand itself, is equal to the force with which it is compressed, just as it is in the spring of a watch, which exerts no force, but in proportion as it is wound up. If a quantity of air, therefore, is included in a vessel, and is of the same density with the surrounding air, its pressure against the sides of the vessel is equal to that produced by the external atmosphere. Hence it is that we can break a square glass bottle, either by the

direct pressure of the atmosphere, after the air has been extracted from it, or by removing the pressure of the atmosphere, and allowing the elasticity of the air within to exert its expansive force.

It is owing to the elasticity of the air that it is susceptible of dilatation and compression. To what degree air of the same density which it possesses at the surface of the earth is capable of being compressed, has not yet been fully ascertained. Dr. Halley informs us that he has seen it compressed, so as to be sixty times denser than in its natural state. Some have supposed that no bounds can be fixed to the condensation of air. But it appears from some experiments made in London, and by the Academy of Florence, that no force whatever is able to reduce air into eight hundred times less space than that which it naturally possesses at the surface of the earth. It is owing to the power of being artificially condensed, that forcing-pumps produce their effects, and that an air-gun is enabled to discharge a ball to a considerable distance with great violence. The air is forced into a certain compartment of the gun by means of a syringe or condenser, which drives the air in, and suffers none of it to come back till it be sufficiently condensed. When the valve which confines the air is opened, the air by its elastic power rushes in behind the ball, and forces it out of the barrel with great violence. It would be better for mankind, however, that no such

instruments were ever constructed. Science ought always to have for its object the construction of instruments and machines which have a tendency to promote the comforts of mankind, not those which may be employed by unprincipled men as weapons of destruction; and, therefore, the construction of this instrument is alluded to merely as an illustration of the powerful effect of the elasticity of the air. Would to God that guns, and cannons, and warlike instruments of all descriptions were for ever unknown among men; that swords were beaten into ploughshares, and spears into pruning-hooks; that nation might no longer lift up sword against nation, but delight themselves in peace!

The dilatation or expansion of air, in virtue of its elastic force, is found to be very surprising. In several experiments made by the honourable Mr. Boyle, it dilated first into nine times its former space, then into thirty-one times, then into sixty, and then into one hundred and fifty. Afterwards, it was brought to dilate 8,000 times its space, then into 10,000 times; and, at last, into 13,679 times the space it originally occupied, and all this was effected by its own expansive force, without the help of fire, or the principle of heat. Hence it appears that the air we breathe near the surface of the earth is compressed by its own weight into at least the 13,000th part of the space it would occupy *in vacuo*. And, as it has been found that it may be compressed into

a space sixty times less than that which it generally occupies, it follows, that the space which it will possess when most dilated, to that which it occupies when condensed, will be nearly as 820,000 to one! The amazing force of this elastic power of the air, were it properly directed, might be made to act as a strong mechanical power, and there can be little doubt that many of the terrific operations of nature—such as earthquakes, volcanoes, the rising of new islands from the bottom of the ocean, and the detachment of rocks and fragments of mountains amidst the ranges of the Alps, the Andes, and other mountainous regions—are to be ascribed, at least to the partial operation of this power, in combination with other physical agents.

It has been a subject of inquiry among philosophers, whether the elastic power of the air is capable of being diminished or destroyed. Mr. Boyle endeavoured to discover how long air would retain its spring, after having assumed the greatest degree of expansion his air-pump could give it, but he never observed any sensible diminution. Mr. Desaguliers says, that air, which had been inclosed half-a-year in a wind-gun, had lost none of its expansive power; and Mr. Roberval asserts that he has preserved air in the same manner for sixteen years; and after that period, he observed that its projectile force was the same as if it had been newly condensed.

Various causes have been assigned by phi-

losophers to account for the elasticity of the atmosphere. The general opinion which now prevails is, that it depends upon the latent caloric, or principle of heat, which it contains, and which enables it to retain its fluid form; and that caloric is the most elastic body in nature. But this is only an explanation of elasticity by an assumption of elasticity. It removes the difficulty only one step farther on, and leaves us still in the dark as to the nature of elasticity, and the reason why caloric is endowed with an elastic power. In this, as well as in many other instances, we must rest contented in resolving it into the will of the Deity, that such a property should be possessed by atmospheric air in order to accomplish some wise and beneficent purposes in the economy of creation.

The elasticity of the air explains a variety of appearances in nature and art. For example, beer or ale, when bottled, contains in it a quantity of air, the elasticity of which is resisted by the pressure of the condensed air between the cork and the surface of the liquid. On removing the cork, the liquid and the air which it contains are relieved from this intense pressure. The liquid itself, not being elastic, is not affected by this; but the elastic force of the condensed air, which has been fixed in it, having no adequate resistance, immediately escapes, and rises in bubbles to the surface, and produces the frothy appearance consequent upon opening the bottle. On a similar prin-

ciple we may account for the following appearance. If a man fall into the water, and is drowned, the carcase in a few days rises and floats on the surface. The privation of life, and the stagnation of the fluids, are soon followed by a putrid fermentation which decomposes the body. This fermentation disengages a great quantity of air, which is disseminated among the internal vessels, and as this air cannot escape, the body swells by its expansion, till it becomes specifically lighter than the water, and rises to its surface. But, as the putrefaction goes on, the parts give way, the air escapes, and the body being thus rendered specifically heavier than the water, sinks to rise no more. It is likewise by the elastic property of air that fishes are enabled to rise and sink in the water. They are furnished with an air-bladder, which they have the power of contracting or dilating at pleasure. When the fish compresses this bladder, its whole volume becomes less, and it sinks in the water; when the pressure is removed, the air in the bladder instantly expands, and it is enabled to rise to the surface. A variety of instances of a similar kind, illustrative of the elasticity of the air, might be exhibited; but instead of dwelling on these, we shall now proceed to another department of our subject.

CHAPTER V.

The height of the atmosphere; or, the elevation to which it extends beyond the surface of the earth.

THE height of the atmosphere is considered, by many writers and lecturers on this subject, as a point fully determined, and is treated as familiarly as the height of the Andes or the Alps, or of Mount Etna or Mount Blanc. But the height of the atmosphere has never yet been fully ascertained, and, it is probable, will never be accurately determined. If, indeed, the air were of an equal density, from the surface of the earth to the top of the atmosphere, its height might be easily determined; for it is found by experiment, that the weight of a column of air extending to the top of the atmosphere, is equal to the weight of a column of water of the same base and 32 feet high. Supposing water to be 840 times heavier than air—multiply 840 by 32 feet, and the product will be 26,880 feet, or 5 miles and 160 yards for the height of the atmosphere, were its density at every elevation exactly the same as

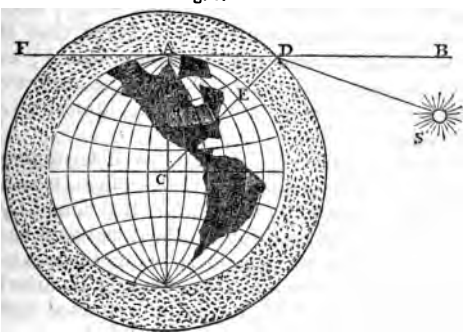
at the surface of the earth. But we know that the density of the air decreases and is more rarefied and expanded the higher we go; and, from other considerations we know that it extends far beyond the limit now stated; so that this calculation can afford us no accurate idea of the height to which the atmosphere extends.

Another method, therefore, of determining this point was devised by philosophers, which approaches nearer to the truth. It is found by observation, that the sun is about eighteen degrees below the horizon before twilight comes to an end in the evening. Now, twilight is caused by the rays of the sun being refracted and reflected from the higher parts of the atmosphere to the earth; otherwise, we should be involved in total darkness at the moment the sun descended below the horizon. From this circumstance, the height of the highest part of the atmosphere which is capable of refracting the rays of light may be determined.

Let F A B (fig. 5) represent the horizon of an observer at A; S D, a ray of light falling upon the atmosphere at D, and making an angle, S D B, of 18° with the horizon; the angle S D A will then be 162°. From the centre C, draw C D, and it will be perpendicular to the reflecting particles at D, and will likewise bisect the angle S D A. In the right-angled triangle C D A, the angle C D A is equal to 81°; or, if we allow for refraction, 81° 30′, A C, the *radius*, or half-diameter of the earth, is nearly

equal to 4000 miles. Then, by the rules of trigonometry,

Fig. 5.



As the sine of the angle C D A ..	81° 30′ ..	9.995203
Is to the side A C, ...	4000 ..	3.602060
So is radius, sine of 90°	..	10.000000
To the side C D, 4044½ miles		3.606857

From C D, equal to the semi-diameter of the earth and atmosphere, subtract C A, or the semi-diameter of the earth, and the remainder, E D, equal to 44½ miles, will be the height of the atmosphere. In this operation, the logarithms of the second and third terms of the proportion are added, and the logarithm of the first term subtracted from the sum.

Thus	3.602060
	10.000000
	13.602060
	9.995203
	3.606857

The same result is produced by the following proportion:—

As Radius.....	10.000000
Is to A C 4000	3.602060
So is the secant of A C D = 8½°	10.004800
To C D = 4044½	3.606860

It appears, then, that in ordinary cases, the air, at the height of forty-four miles and a half, is capable of reflecting to us the rays of light. But, as a sensible illumination has been perceived when the sun is much further below the horizon than what has been now stated, there is some reason to conclude, that the air is sufficiently dense for reflecting a sensible degree of light at the height of nearly two hundred miles.

Various considerations, founded on meteoric phenomena, serve to prove that the atmosphere extends to a much higher elevation than forty-four or fifty miles. In the year 1719, a remarkable luminous meteor, or fire-ball, was seen, whose altitude was computed to be seventy-three miles above the surface of the earth. On the 18th of August, 1783, a brilliant fire-ball passed over Britain and the adjacent countries; and, from various circumstances which were particularly marked by different observers, it was calculated that its elevation above the earth could not be less than ninety or a hundred miles. In passing over certain parts of England, a loud report was *heard and a* hissing noise. The meteor of

1719 is said to have been attended with an explosion, which was heard over the whole island of Great Britain, occasioning a violent concussion of the atmosphere, and seeming to shake even the earth itself. Now, in these, and multitudes of similar phenomena, we have instances of fire and flame being supported, and sounds conveyed to the earth from a height of ninety or a hundred miles; and, consequently, even in these elevated regions, notwithstanding the great rarefaction of the air, it must still have the power of supporting flame and propagating sound. Even although the fire-balls alluded to be supposed to consist of electrical matter—which is the general opinion—yet the difficulty is not thereby removed; for, it is found, by some late experiments, that the electrical fire cannot penetrate a perfect vacuum. And, therefore, there is reason to conclude, that we are still ignorant of the precise extent of the atmosphere, and of the nature of the fluids which occupy its superior regions. That the meteors now referred to, however elevated, were not beyond the limits of the atmosphere, appears from this consideration, that the atmosphere revolves with the earth in its course round the sun, at the rate of 68,000 miles an hour. Now, as the meteor of 1783 moved from north to south, if it had been beyond the limits of the atmosphere, it would have been left, in the course of a minute, more than a thousand miles to the westward, by the earth

flying out before it, both in its annual and diurnal course.

In short, it appears not altogether improbable to suppose, that the visible universe is filled with some fine elastic fluid or air, but of such a rarity as to be no sensible hindrance to the celestial orbs in their rapid motions through the regions of space; and that this fluid accumulates itself around every planetary body, in proportion to the quantity of matter it contains—the larger bodies attracting more of it, and the smaller bodies less; and thus forming an atmosphere around each, corresponding to its nature and destination. And, if this be the case, the atmosphere of the earth can have no definite boundary, but may be said to mingle with the atmospheres of all the other planets which belong to our system. There is a certain portion of atmospheric air, however, which must always be considered as attached to the earth, and which revolves with it in its diurnal rotation, and is carried along with it in its course round the sun. If the atmosphere did not revolve along with the earth, we should constantly experience an easterly wind, blowing with an immense velocity of more than a thousand miles an hour, which would produce a most tremendous hurricane, which would level with the ground houses, trees, forests, and every prominent object on the surface of the earth. But the particular region where the motion of the atmosphere terminates, it is impossible for us to ascertain.

CHAPTER VI.

The composition of the atmosphere.

For a long series of ages, air was considered by philosophers as one of the four elements of which all things are composed, the other three being fire, earth, and water. But the discoveries of modern chemistry have fully demonstrated that all these are compound bodies—that even the air itself, fine and invisible as it is, is not a simple substance, but compounded of different ingredients. This is one of the most curious and interesting discoveries of modern times; and little more than seventy years have elapsed since it was first surmised that the atmosphere is not a simple and homogeneous, but a compound fluid. The experiments which led to this discovery were first made by Dr. Priestley, on the first of August, 1774, on which day he obtained what was then termed dephlogisticated air, now known by the name of oxygen gas, and which forms one of the constituent principles of atmospheric air. It was also discovered in the year 1775, by M. Scheele, a Swedish chemist, without

any previous knowledge of what Dr. Priestley had done, and he gave it the name of empyreal air, from its powerful influence in supporting flame. But, instead of entering into the history of such discoveries, and of the processes by which they were made, a few of the properties possessed by the different ingredients of which our atmosphere is composed may be simply stated.

The air of the atmosphere, then, is found to consist chiefly of two very opposite principles or fluids, termed oxygen gas, and nitrogen gas, along with a very small proportion of fixed air, or carbonic-acid gas. If any portion of the atmosphere, such as the air in our apartments, be supposed to be divided into an hundred equal parts, twenty-one of these parts will be oxygen gas, about seventy-eight nitrogen, and a hundredth part, or, according to some chemists, a thousandth part, will be fixed air, or carbonic-acid gas. In the first place, a few remarks shall be offered on the nature and properties of oxygen gas.

This gas, like common air, is colourless, invisible, and elastic, and capable of indefinite compression and expansion. Its peculiar and distinguishing properties are :—1st. It is essential to combustion, and is the only principle with which we are acquainted by which flame can be supported. When acting by itself, it produces the most rapid conflagration of all combustible substances. If a lighted taper be let down in a jar of oxygen gas, it burns with

such splendour that the eye can scarcely bear the glare of light, and, at the same time, produces a much greater heat than when burning in common air. If a piece of iron wire, a watch-spring, or a steel file, armed with a piece of wood, or phosphorus, in an inflammable state, be put into this gas, the steel will take fire, throwing out sparks, and producing the most brilliant appearance, almost dazzling the eye with their splendour. In the next place, it is essential to the support of animal life; for it has been proved by many experiments, that no animal can exist for a single moment in any kind of air which does not contain a certain portion of oxygen; so that man, and all the other ranks of animated beings, may be said to depend upon this substance, not only for their comforts, but for their very existence.

Again, the basis of oxygen gives the acid character to all mineral and vegetable salts, from which property its name is derived; for the term oxygen literally signifies, the generator of acids. In short, oxygen is the vehicle of heat to the animal system—it imparts the red colour to the blood in its passage through the lungs—it constitutes the basis both of the atmosphere which surrounds the earth, and of the water which forms its rivers, seas, and oceans; for water is found to be nothing else than a combination of two kinds of air, oxygen and hydrogen gas. It pervades the substance of all the vegetable tribes, and enables them to perform their functions. In combination with

the different metals, it serves the most important purposes in the useful arts; and, on the whole, may be considered as the most extensively useful, and the most powerful and energetic agent in the system of nature.

Oxygen gas may be procured from a variety of substances, particularly from nitre, manganese, and the red oxyde of mercury, and also from vegetables immersed in water, and exposed to the solar rays. It is heavier than common air, nearly in the proportion of eleven to ten; one hundred and sixteen cubic inches of oxygen are found to weigh about thirty-nine grains, while the same quantity of common air weighs only thirty-five and a half grains.

One of the most extraordinary effects of oxygen appears when it is combined with nitrogen in a certain proportion, so as to form what is commonly called nitrous oxyde. This gas consists of sixty-three parts nitrogen and thirty-seven parts oxygen. When it is put into a bladder, and inhaled into the lungs, by means of a pipe, and shutting the nostrils, it produces an extraordinary elevation of the animal spirits—involuntary muscular motion—a propensity to leaping and dancing—involuntary bursts of laughter—a rapid flow of vivid and agreeable ideas, and a thousand delightful emotions, without being succeeded by any subsequent feelings of languor or debility. When Mr. Southey, the poet, inhaled this gas, he declared that it produced in him sensations perfectly new and delightful. His

first sensations were a kind of dizziness, so as to produce a fear of falling. This was succeeded by a laugh which was involuntary, but highly pleasurable, accompanied with a peculiar thrilling in the extremities perfectly new, and with the most delightful sensations. For many hours after this experiment, he imagined that his taste and smell were more acute, and is certain that he felt unusually strong and cheerful.

In professor Silliman's *American Journal of Science*, we have the following account of the effects of this air on one of the professor's students, at Yale College, New Haven. "The person on whom the experiment was made, was a man of a mature age, and of a grave character. For nearly two years previous to his taking the gas, his health was so very delicate, and his mind so gloomy and distressed, that he was obliged almost entirely to discontinue his studies. In this state of debility, he inhaled about three quarts of the nitrous oxyde. The consequences were, an astonishing invigoration of the whole system, and the most exquisite perception of delight. These were manifested by an uncommon disposition for mirth and pleasantry, and by extraordinary muscular power. The effects of the gas were felt without diminution for at least thirty hours; and, in a greater or less degree, for more than a week. But the most remarkable effect was upon the organs of taste. Before taking the gas, he felt no peculiar choice in the articles of food; but, immediately after that event, he manifested a taste for such things

only as were sweet, and, for several days, ate nothing but sweet cake. His singular taste was, indeed, carried to such excess, that he used sugar and molasses, not only upon his bread and butter and lighter food, but even upon his fresh meat and vegetables; and this he continues to do (says the narrator) at the present time, although eight days have elapsed since he inhaled the gas. His health and spirits since that time have been uniformly good, and he attributes the restoration of strength and mental energy to the influence of the nitrous oxyde. He is quite regular in his mind, and now experiences no uncommon exhilaration, but is habitually cheerful, whereas, before, he was habitually grave, and even, to a degree, gloomy and melancholy."

The writer has inhaled this gas, and can attest its pleasing and exhilarating effects. It produced a disposition to laughter, which no consideration could resist, and a wish to flee from the apartment in which the experiment was performed, that laughter might be indulged without restraint. It produced, likewise, an agility and a tendency to skip and jump; and, during its effect, a flow of pleasing ideas passed through the mind, and the lapse of a few seconds seemed to be magnified into as many hours. He has witnessed its effects both on the male and on the female sex. He has seen a little grave man, possessed of a meek and well-cultivated mind, capering through a room with all *the airs of* a king, brandishing his staff, and

jumping till his head nearly touched the ceiling of the room, about eight feet high. When, afterwards, asked why he brandished his stick, as if he had been going to fight, he replied, that he imagined there was a beautiful and extensive scene before him, which he wished to approach; but was prevented by the company around him, and, therefore, was obliged to clear his way, like a policeman when keeping off a crowd. The writer has, also, seen a female rapt into perfect ecstasy in consequence of the feelings she experienced, expressing her emotions in the most poetic exclamations, and tossing her shawl, her head-dress, and her slippers, from her as unworthy of attention, and altogether regardless of the looks and opinions of surrounding spectators. But, in order that this gas may produce its full effect, it requires some attention and dexterity in breathing it. The nostrils must be stopped, and no atmospheric air, if possible, should be allowed to mix with the nitrous oxyde. For want of attending to such precautions, some persons who attempt to breathe it, never feel its peculiar effects.

It has been ascertained from various experiments, particularly from those made by the late sir Humphrey Davy, that the nitrous oxyde produces a somewhat similar effect upon insects, and other animals, which are found to jump and caper about in a frolicsome manner, as if highly delighted, when immersed in this gas.

These, and other effects, arising from the breathing of this very singular fluid, show us with what ease the Almighty could produce in us either the most delightful or the most painful sensations, merely by a slight modification or change of the principles of which the atmosphere is composed. Certain combinations of oxygen and nitrogen gas would produce a fluid, which would inflict the most excruciating pain, and destroy the corporeal system in a few minutes. Sulphuric acid, or aquafortis, a most deadly fluid, when taken into the mouth or stomach, is composed of seventy-five parts oxygen and twenty-five parts nitrogen, which is only a different proportion of the same ingredients which constitute the air we breathe. Were, therefore, our atmosphere composed of such a proportion of these two gases, it is easy to foresee the fatal consequences which would result from breathing such a fluid. On the other hand, we may learn how an intelligent mind connected with a corporeal frame, somewhat analogous to ours, may be preserved in a state of uniform cheerfulness, and even of exquisite delight, by breathing an atmosphere somewhat similar to that of the nitrous oxyde. In other worlds, where the inhabitants have retained their original integrity, this may be the case. The other planets of our system or of other systems, although encompassed with atmospheres may have them of very different qualities from ours, as to their transparency, their refractive and reflective powers, and the influence

they produce on the mental and corporeal constitution of their inhabitants. Our atmosphere exhibits evident marks of Divine wisdom and benevolence; but it is adapted to man considered as in a state of depravity and imperfection, and appointed to a short mortal existence, and is not fitted to preserve him in an immortal existence in the present state, as was probably the case when this world was first arranged, and when man proceeded from the hands of his Creator as a holy being.

The next component part of the atmosphere is nitrogen gas, or what is sometimes termed azote. It is chiefly distinguished by its negative qualities. In the first place, no combustible body will burn in it; for, if a burning candle be immersed in a jar filled with nitrogen, it will be extinguished as instantaneously as if plunged in water. If a lighted taper be put into a close vessel full of common air, it will burn till all the oxygen be consumed, after which, as nothing but nitrogen remains, it will instantly go out. In the next place, it is incapable of supporting animal life; for, if any living being be obliged to respire it, it drops down dead almost instantaneously; and, from this circumstance, it derived the name of azote, which signifies life-depriver. It is this gas which passes from the lungs at every expiration; and, were we to breathe it again, without any mixture of other air, we should be instantly suffocated. But, being lighter than atmospheric air, it rises above our heads, and enters into new combinations. It is

owing to the presence of this gas, rising from several hundreds or thousands of lungs, that candles burn so dimly in the higher parts of crowded churches and assemblies. It is, therefore, a striking consideration, that nearly four-fifths of the air we breathe consist of this noxious and destructive fluid. But, though it is destructive to animal life, it forms an important element in the system of nature: it enters extensively into combination with other substances; and its existence in such a large quantity is a chief distinction between the constitution of animal and vegetable matter. It likewise exists in the products of several vegetables, and appears to be favourable to plants and flowers, which vegetate freely when surrounded with nitrogen. This gas is permanently elastic, transparent, colourless, and inodorous. Its specific gravity is 0·9748, that of common air being 1·0000; and one hundred cubic inches of it weigh about thirty grains. It slightly tinges delicate blue colours with green.

The other ingredient mentioned as forming a small portion of the atmosphere, is carbonic-acid gas, or what was formerly called fixed air. This gas constitutes about a hundredth, or, according to some chemists, about a thousandth part of the atmosphere. It is found in a state of combination with limestone, chalk, marble, manganese, and other substances, from which it may be extracted by the application of heat, or of the mineral acids, and in considerable *abundance in* mines, caves, the bottom of wells,

in wine-cellars, brewers' vats, and in the neighbourhood of lime-kilns. It is invisible and elastic, and is the heaviest of all the gases, being considerably heavier than common air; and, therefore, may be poured from one vessel to another, like water. Its specific gravity is 1·5123, that of common air being reckoned 1·0000, so that its gravity is more than one and a half that of atmospheric air. One hundred cubic inches of oxygen weigh nearly thirty-four grains, while one hundred cubic inches of carbonic acid weigh more than forty-six and a half grains. It is this gas which has deprived of life many individuals who have descended into deep wells which had been long shut up from the air, and which produces so many ravages in coal-mines, under the name of the choke-damp; for it is almost instantaneously fatal to all animals that breathe it. Wherever it is found, it always occupies the lowest place, on account of its superior weight; and, therefore, in those caves where it abounds, a person may walk erect without danger; but, were he to lie down, he would be instantly suffocated. The Grotto del Cani, or the Dog's Grotto, in Italy, is well known. It is an artificial cave, in which there is a constant natural exhalation of carbonic-acid gas. The following feat is shown to strangers:—a man carries in a dog, and places him on the floor; the dog, if left long enough, dies; but the man is not affected; for the carbonic-acid gas, by its weight, occupies the lowest stratum of about eighteen inches

depth, and the stratum above that height is pure air. But that it is poisonous to man, is evinced by the fate of persons who incautiously expose themselves to the vapours of charcoal burning in ill-ventilated apartments, or who venture into large vessels, in which fermentation had been conducted, as in breweries and distilleries. Many persons, from ignorance of the prevalence of this gas in the vicinity of lime-works, have lain down to repose, and in a short time have slept the sleep of death. As this gas is destructive to animal life, so it extinguishes flame. This can be strikingly shown by letting down a burning taper to the bottom of a glass jar, filling a bottle with carbonic-acid gas, and pouring it as if it were water into the jar, the flame is immediately extinguished. It is this gas which gives briskness and an agreeable pungency to fermented liquors, as porter and ale, and which appears on their surface in the form of a white froth. All kinds of spring and well water contain carbonic-acid, which they absorb from the atmosphere, and to which they are partly indebted for their agreeable flavour. Boiled water has an insipid taste from the absence of carbonic-acid.

The base of carbonic-acid gas is distinguished by the name carbon, which is nearly allied to charcoal. It exists largely in animal substances, and is extensively distributed in the mineral kingdom. The only body in which carbon has been found to exist in a state of absolute purity, *is the diamond*—a precious stone, which has

always been esteemed as the most valuable of the gems; a superiority which it owes to its hardness, lustre, and high refractive power. It uniformly occurs crystallized, and presents a great variety of forms. Its specific gravity is 3·5, water being 1. Its hardness is extreme, so that it can be worn down only by rubbing one diamond against another, and is polished only by the finer diamond powder. The diamond, by being intensely heated with a burning-glass in oxygen gas, burns with a bright red light, and converts the oxygen into pure carbonic-acid gas, as charcoal does. Carbonic-acid gas is, therefore, to be considered as a solution of diamond in oxygen gas, even when it is prepared by the combustion of mere charcoal. It may not be altogether useless to remark, that in all places, such as wine-cellars, vaults, and deep wells, where the presence of carbonic-acid gas is suspected, it is proper to use the precaution of trying whether a candle or taper will burn in such places before we venture into them. If it be a deep well that requires to be cleaned, a burning candle should be let down with a cord, and if it go out before reaching the bottom of the well, no person ought to venture down before the noxious air is removed.

Such, then, are the three constituent principles of the atmosphere in which we live and breathe. We ought not, however, to conceive that the principles which form our atmosphere, and the proportion in which they are combined, constitute the only fluid which is fitted for

supporting animal life and vigour. It is a fluid which seems to be adapted only to mortal men, and calculated to support the vital functions only to the period of eighty or one hundred years. It is not at all improbable, that it is owing to the large proportion of nitrogen which enters into the composition of the atmosphere that renders it unfit for supporting human life beyond a certain short and limited period; and that, were a much larger quantity of oxygen combined with other gases, in a certain proportion, and some slight changes effected in the other elements of nature, the lives of men and other animals might be protracted to several hundreds or thousands of years, and their spirits preserved, at the same time, in uninterrupted cheerfulness and vigour. Nor is it altogether improbable that, in the course of those improvements which are now commencing throughout the world, the air of our atmosphere may be greatly ameliorated, and rendered more salubrious and invigorating to animated beings, when the stagnant marshes which abound in every part of the globe shall be completely drained—when those immense forests which now cover a great part of Asia, of New Holland, and of the continent of America, shall be cut down, and the soil laid open to the influence of the solar rays—when the reefs which are now rising from the ocean, by the agency of minute creatures, shall be formed into continents and islands—when the barren deserts of Africa shall be transformed, by human science and

industry, into fruitful fields—when the soil throughout every region of the globe shall be universally cultivated—when those immense thickets and jungles where the lion and the tiger now roam undisturbed, shall be changed into corn-fields, gardens, and orchards, and become the seats of civilisation and of peace—in short, when the whole earth shall form one wide scene of rural and architectural beauty—we have every reason to believe that then the different climates of the earth will be greatly meliorated; that the fury of those storms which now carry destruction in their train will be greatly abated—and that the very atmosphere around us will be so modified, purified, and improved, as to render it capable of prolonging the life of man for perhaps two or three hundred years. Such effects correspond to what is predicted respecting the state of the world during the millennium, when the instruments of warfare shall be beaten into ploughshares and pruning-hooks; when peace shall reign triumphant over the world, and when every man shall sit under his vine and fig-tree without fear of annoyance. At which period, it is predicted, that the life of man shall be extended beyond its present boundaries. For thus saith Jehovah, "As the days of a tree* are the days of my people"—"they shall build houses, and inhabit them; and they shall plant

* Certain species of trees are said to continue in vigour during a period of five hundred years, as the oak and several other trees.

vineyards and eat the fruit of them; ... and mine elect shall long enjoy the work of their hands." "Then shall the earth yield her increase; and God, even our own God, shall bless us."

All the operations and ameliorations now alluded to are perfectly practicable, were the moral state of man improved. Could we undermine the principle of avarice and selfishness in the human heart; could we promote a spirit of harmony and general benevolence among human beings; and were the whole body of mankind to exert their powers in unison, in the cause of universal improvement—this earth, which, in many places, appears like a world in ruins, might, ere long, be transformed into one wide terrestrial paradise. But principles and dispositions directly opposite to these have, for the most part, hitherto prevailed. The present state of the moral world, and the infernal passions which have raged among mankind for ages past, have rendered it expedient, in the moral government of the Almighty, that the life of man should not extend much beyond "threescore years and ten," in order that wickedness may be kept within certain bounds. And, therefore, no extraordinary or extensive improvements in science and art, or in the general cultivation of the earth, can be expected till the moral powers of man be cultivated and improved along with the intellectual; till the religion of Jesus be universally recognised in all *its bearings*; till its holy principles and practical

precepts pervade every heart; and till a spirit of love, kindly affection, and benevolence distinguish the general mass of society in every land.

But, to return from this digression, it may be further remarked, that it is highly probable that the component parts of the atmosphere, in the ages before the flood, were very different from what they now are, and that it was owing to the peculiar constitution of the air which then existed, that the lives of the antediluvians were prolonged to nearly a thousand years. At the period of that awful catastrophe, when the fountains of the great deep were broken up, and the windows of heaven were opened, and the solid strata of the earth disrupted, it is probable that the atmosphere, too, underwent an important change by the dissolution of some of its elementary parts, so that it had a tendency to cut short the lives of mankind in all succeeding ages; and, till the ruins which were produced by that physical convulsion be in some measure repaired, the same cause will produce the same effects.

In short, an atmosphere is not peculiar to the globe on which we dwell. We know, from observation, that the planets Mars, Venus, and Jupiter, are furnished with atmospheres; and it is probable that every planetary world has a similar appendage. But their nature may be as different from ours, as are the nature of their inhabitants and the constitution of the globes on which they reside. While our atmosphere is fitted only to prolong the lives of mortal men

for a limited number of years, the atmospheres of some of the other planets may be so impregnated with the vital principle as to support immortal bodies in undecaying vigour, and to cause such an elevation of spirits as will produce uninterrupted ecstasy and delight. And all this may be effected by the same elementary principles of which our atmosphere is composed, but differently modified and compounded by the hand of the Almighty. The experiments with nitrous oxyde, formerly mentioned, show us what striking effects may be produced by different combinations of the gaseous fluids; and, therefore, it is not improbable that the atmospheres of all the worlds in the universe are only different modifications of these substances, suited to the constitutions of their inhabitants, and the spheres they occupy in creation. In the operations of the Almighty throughout the system of nature, we perceive a striking simplicity in the means, producing an infinite variety of astonishing results. From a few simple substances—caloric, light, water, air, and carbon—are produced all the diversity of forms and colours which appear among the sixty thousand species of plants which adorn the vegetable kingdom, and almost all the diversified phenomena of sublunary nature. And it is not unlikely that different combinations of these, and a few other substances, produce all that variety which appears throughout the boundless universe; and may give birth *to all the* changes and revolutions through

which the different systems of creation may pass during every period of infinite duration. For He who arranged the system of universal nature "is wonderful in counsel, and excellent in working"—"his wisdom is unsearchable," his power irresistible, and the ways of his providence "past finding out."

CHAPTER VII.

The beneficial effects of the atmosphere in the system of nature.

THIS subject presents an immense field of contemplation, which it would require several volumes fully to illustrate; and, therefore, a few general statements and illustrations can only be given.

1. In the first place, air is essentially requisite to the germination and growth of plants; and, therefore, to the influence of atmospheric air, all the beauties of the vegetable creation are to be chiefly ascribed. By experiment, it is found that the access of atmospheric air is no less necessary for plants than it is for the continuation of animal life. Like animals, they are found to die when confined within a vacuum, or deprived of the vital air. The influence of the atmosphere is equally essential at every period of their existence, from the germination of their seeds to the full development of all their organs in the perfect plant. Their leaves, acting in some measure like the lungs of animals, absorb oxygen gas during the night, and carbonic-acid gas during the day;

and this alternate process is found to be essential to their growth and nourishment. Even the green colour of plants, which is produced chiefly by the influence of light, is proved not to be perfected without the co-operation of oxygen gas. It is found that pure air, or oxygen gas, may be procured by putting the leaves of plants into water, and exposing them to the sun. In purifying contaminated air, Dr. Priestley discovered that vegetables answered this purpose most effectually. Having rendered a quantity of air very noxious, by mice breathing and dying in it, he divided it into two receivers, inverted in water, introducing a sprig of mint into one of them, and keeping the other receiver, with the contaminated air in it, alone. He found, in about eight or nine days after, that the air of the receiver into which he had introduced the sprig of mint had become respirable; for a mouse lived very well in this, but died immediately upon being introduced into the other receiver, containing the contaminated air alone. It is likewise proved by experiment, that the simple component principles which are essential to the formation of vegetable matter are but three in number, namely, carbon, oxygen, and hydrogen; and these form the bases of carbonic-acid gas, oxygen gas, and hydrogen gas. From the various proportions in which these ingredients are combined, results almost all the variety of vegetable matters which fall under our notice.

To the atmospheric influence, therefore, we

are indebted for all the productions of our fields and gardens, and for all that diversity of prospect and colouring which the vegetable tribes spread over the landscape of the world. It is true, indeed, that water is also necessary for the production of plants. But what is water? It is nothing else than a composition of two kinds of air, oxygen and hydrogen, combined in certain proportions. Now, it is found that plants have the power of decomposing water into these two principles, throwing off a part of the one, and absorbing a part of the other. The elasticity of the air has likewise an important influence on the air-vessels of vegetables; for the contained air, alternately expanding and contracting, according to the increase or diminution of the heat, alternately presses the vessels, and eases them again, thus keeping up a perpetual motion of their juices. It has likewise been ascertained, from recent experiments, that the pressure of the atmosphere has a powerful influence on vegetation, which suggests to us one of those causes which prevent trees from flourishing on the elevated sides of lofty mountains.

2. The pressure of the atmosphere has an influence in preserving water in the state in which we find it. Nothing is of more importance to the comfort of man and other creatures, and to almost all the processes of the arts, than water—without which our globe would be transformed into an immense desert. But, if *there* were no atmosphere, all the waters on

the face of the earth would boil, and be evaporated with a very slight degree of heat. The ocean would be drained to its lowest caverns, the rivers would cease to flow, the springs would be dried up, and the whole surface of the land exhausted of that moisture so essential to the existence of the animal and vegetable world. Indeed, it is not improbable, that all the substances on the earth, solid as well as fluid, would be dissipated into vapour. That such effects would actually take place, appears from a variety of experiments. If we fill a long-necked bottle with boiling water, and cork it close, so as to exclude the air, and place it in a bason of cold water, the water will sink in the neck of the bottle as it cools. This shrinking of the water will produce a vacuum in the upper part of the bottle, and the water within it will be seen to re-commence boiling with great violence, which can arise from nothing but the cork taking off the pressure of the atmosphere from the water. In like manner, if we place water that has been cooled several degrees below boiling, under the receiver of the air-pump, it will begin to boil as soon as the air is exhausted. It requires a heat of 212° of Fahrenheit's thermometer to make water boil under the common pressure of the atmosphere; but in the exhausted receiver of an air-pump, it boils when heated to only about 67°. The phenomenon exhibited by what is called the pulse-glass, is also owing to the same cause. This glass, having two bulbs, is partly

filled with spirits of wine, the air is extracted, and the glass hermetically sealed; and when the hand is applied to one of the bulbs, it causes a heat which produces an ebullition in the spirits of wine. It is likewise owing to this pressure that porter, ale, and other fermented liquors are preserved in bottles; without which they would either rush with violence out of their mouths, or burst them to pieces. It is owing to the same power that boiling water is preserved in our pots and kettles, when used in cooking, without the influence of which it would soon dilate itself, rush over the vessels, and be dissipated into vapour.

3. It is to the atmosphere we are indebted for the action of fire and flame. Fire is essentially necessary to human existence, even in the warmest climates of the globe. By its means the inhabitant of the desert frightens from his dwelling the beasts of prey, and drives away the insects which thirst for his blood. By its means also, man, in every country, prepares his food, dissolves the metals, vitrifies rocks, hardens clay, softens iron, tempers steel, and gives to all the productions of the earth the form and combinations which his comfort and necessities require. But, without the vital air, no flame can be extricated, nor fire made to burn. This is proved by putting a burning taper within the receiver of an air-pump, and when the air is extracted it is instantly extinguished. The act of combustion effects an *analysis of* the air; it separates its component

parts: the oxygen of the atmosphere combines with the combustible body, caloric, in the form of sensible heat, is thrown off in every direction; and therefore, where no oxygen exists, it is impossible to make even the most combustible body produce heat or flame.

4. It is on the influence of the atmosphere that the respiration of all animals depends. The process of respiration is carried on by means of the lungs. These are distinguished into right and left. The right, or larger lung, is divided into three lobes; the left, or smaller, into two. The internal fabric of the lungs is composed of an infinite number of small membranous cells, full of air, communicating with one another, the number of which Dr. Keil and other anatomists have computed to be at least 1,744,000,000, that is, one thousand seven hundred and forty-four millions. The air from without rushes into these vesicles, and is again expelled 1,200 times every hour; and during the same time we consume about 48,000 cubic inches of air, or, at the rate of seventy-seven wine hogsheads in a day. The chief uses of respiration are—1, to bring the blood in contact with the air; 2, to effect certain changes in the mass of the blood; and 3, to produce animal heat. Accordingly, the lungs are so constructed as to allow the largest possible quantity of deteriorated blood to enjoy the fullest intercourse with the largest possible quantity of vital air. It has been calculated by Dr. Hales, that each air cell is the one-

hundredth part of an inch in diameter, and that the amount of surface furnished by them, collectively, is equal to twenty thousand square inches. Others have estimated the surface to be more than 1,500 square feet; and Dr. Monro states, that it is thirty times the surface of the human body. From numerous experiments, it has been found that the blood perpetually receives oxygen gas from the atmosphere by the agency of the lungs, and that its red colour is derived from this source. The blood is purple when it arrives at the lungs from the heart; but, having there thrown off hydrogen and carbon, it imbibes the vital air of the atmosphere, which changes its dark colour to a brilliant red, rendering it the spur to the action of the heart and arteries, and the source of motion and of animal heat. The blood is thus indebted every moment to the invigorating influence of the atmosphere, without which the heart would cease to beat, the circulating fluids would stagnate, and the body become a cold putrid mass, without sensibility or motion.

The following are some of the results of experiments in relation to this subject, lately performed by Dr. S. Smith. "1. The volume of air ordinarily present in the lungs is twelve English pints. 2. The volume of air received by the lungs, at an ordinary inspiration, is one pint. 3. The volume of air expelled from the lungs at an ordinary expiration, is a *little less* than one pint. 4. Of the volume of

air received by the lungs at one inspiration, only one-fourth part is decomposed at one action of the heart, and this is so decomposed, in the five-sixth parts of one second of time. 5. The blood circulates through the system, and returns to the heart in one hundred and sixty seconds of time, which is exactly the time in which the whole volume of air in the lungs is decomposed. These circuits are performed every eight minutes; five hundred and forty circuits are performed every twenty-four hours. 6. The quantity of blood that flows to the lungs, to be acted upon by the air at one action of the heart, is two ounces, and this is acted upon in less than one second of time. 7. The quantity of blood in the whole body of the human adult is twenty-four pounds avoirdupois, or twenty pints. 8. In twenty-four hours, twenty-four hogsheads of blood are presented to the lungs, to receive the influence of the vital air. 9. In the mutual action which takes place between the quantities of air and blood which come in contact in twenty-four hours, the air loses three hundred and twenty-eight ounces of oxygen, and the blood, ten ounces of carbon."

Such are the wonderful processes in reference to respiration as dependent on the atmosphere. When we reflect that a stratum of blood, several hundred feet in surface, is exposed to a stratum of air still more extensive, and all compressed within the compass of a few inches, we cannot but be filled with admiration

at the Divine wisdom displayed in this and many other functions of the human system, which so far surpass all the contrivances of genius, science, and art. In every part of the workmanship of the Almighty, even the most minute, we perceive the impress of infinite goodness and intelligence, demonstrating that He who formed the human frame and the surrounding elements is "wonderful in counsel, and excellent in working." Not only are terrestrial animals and the fowls of heaven dependent for existence on the atmosphere, but even the fishes of the sea cannot subsist for any length of time without its invigorating influence. Every fish is furnished with an air-bladder, by which it is enabled to rise in the water, or sink into it at pleasure. The lungs of fishes are their gills; these consist of filaments, arranged somewhat like the feathers of a quill; they are found to be covered with minute processes, crowded close together, and on which are observed, by the microscope, millions of capillary blood-vessels spread, like a net-work, over the whole surface. It is through the thin coats of these vessels that the air acts upon the blood they contain. When a fish is taken out of the water, the reason it cannot breathe is, that these filaments collapse, and adhere together in a mass, and the air cannot separate them. If the air be extracted from the water in which fishes swim, or if they have no free communication with the air, *they are soon* deprived of existence.

5. The atmosphere is the medium in which the process of evaporation is carried on, and in which clouds, rain, and dew are produced. By the heat of the sun and other causes, an immense portion of matter is daily carried up into the atmosphere in the form of vapour, in which state it occupies a space 1,400 times greater than in its ordinary liquid state. It has been found, by experiment, that an acre of ground, in the course of twelve hours of a summer's day, dispersed into the air, by evaporation, 1,600 gallons of water. Every hour there are exhaled in this way, from the surface of the ocean, many millions of gallons, and every year about 40,000 cubical miles of water. This vast body of water, sometimes in an invisible form, and sometimes in the shape of clouds, is carried by the winds over the different regions of sea and land. A part of this water is condensed into thick clouds, and falls down in rains on the continents and islands to fertilize the soil; a part descends on the seas and oceans; and another part supplies the sources of the rivers, by which it is again returned to the ocean, whence it was chiefly derived. This continued circulation of vapour through the atmospherical regions, is one of the most important processes in the system of nature connected with our globe. By means of it, the Creator displays his wisdom and unbounded benevolence, in conveying fertility to the different climates of the earth, and thus supplying nourishment and comfort to man

and to all the inferior orders of animated existence. But it is evident that, without the ministration of the atmosphere, these beneficent operations could not be carried on, and the earth would be left to parch under the rays of the sun, till it were transformed into a bleak and barren desert. It is owing to this process of evaporation that our clothes and linens are dried, after having been washed, and that our roads are rendered clean for walking upon, after having been drenched with heavy showers of rain, or covered with deep snows; without the operation of which, a thousand discomforts and inconveniences would be felt in all the scenes of domestic life, and the operations of art; and this world would cease to be an abode of happiness and enjoyment.

6. The density of the atmosphere gives buoyancy to the clouds, and enables the feathered songsters to transport themselves with ease from one part of the earth to another. If the air near the earth were much rarer than it is, the clouds would sink to the surface of the earth, involve the world in a dismal gloom, and intercept our views of the beauties of the terrestrial landscape, and of the glories of the midnight sky. The birds would be unable to perch on the tops of lofty trees, or to wing their flight from shore to shore. As a proof of this, Mr. Robertson, who ascended in a balloon from St. Petersburgh, in 1804, informs us that he took along with him some live *pigeons,* and, at different heights, gave liberty

to these birds, who seemed very unwilling to accept of it. The poor animals were so terrified with their situation, that they clung to the boat of the balloon till they were forced from it, when it appeared their fears were not groundless; for their wings were nearly useless, from the rarity of the air, and they fell towards the earth with great rapidity. The second struggled with eagerness to regain the balloon, but in vain; and the third, thrown out at the greatest elevation, fell towards the earth like a stone, so that he supposed it did not reach the earth alive. This was evidently owing to the extreme rarity of the air in those upper regions to which the balloon ascended.

7. The atmosphere is the region in which winds are produced, which perform many important offices in the economy of our globe. Winds are nothing else than portions of air in motion; and although they sometimes excite our fears by the violence of their rage, and scatter destruction by sea and land; yet their agency, on the whole, is highly beneficial, and even essentially necessary to mankind. They purify the air by keeping it in perpetual motion; they disperse the noxious vapours that are continually rising from stagnant marshes and common sewers; they sweep the chambers of the atmosphere; they ventilate the streets of populous cities, and prevent the accumulation of those noxious effluvia which would produce pestilence and death; they scatter the seeds of various plants over every region; they fan the

air under the scorching heats of summer, and diffuse refreshment over a fainting world; they make our millstones revolve as nimbly as the wheels of a chariot, and they serve as wings to our floating edifices, to impel them across the ocean, and to bring them back laden with the treasures of distant lands.

Were the agitation to cease which the wind produces, all nature would be thrown into the utmost confusion. Navigation to distant shores, as hitherto most generally conducted, would be at a stand, and ships would be arrested in the midst of the ocean. The vapours exhaled by the heat of the sun would remain for ever fixed over those particular spots whence they arose, instead of being dispersed, as they now are, over every region. One part of the world, by the interposition of stationary clouds, would be for ever deprived of the direct influence of the solar rays, and of the light of the stars; while, in another part, the soil would be parched, and the grass burned up, for want of a veil of clouds to modify the heat of the sun. One region would be scorched for want of moisture, and another drenched with excessive rains. The putrid exhalations of dunghills, marshes, and populous cities, would remain perpetually suspended around the places whence they arose, and produce diseases and pestilence, which would sweep the inhabitants of the earth in rapid succession to the grave. But in the existing economy of nature, all such disastrous effects are prevented by the agency of the winds,

which distribute the clouds in due proportion over every land, and serve as ventilators to all the regions of the atmosphere.

8. Air is the vehicle of smells, by the transportation of which we become acquainted with the good or bad qualities of the food which is set before us, and are warned against sitting in places that are damp and dangerous, or entering houses that are unwholesome or infectious. By means of the air, the odoriferous effluvia of plants and flowers are diffused over the fields, and conveyed to the nostrils, to increase our delightful sensations, when wandering among the scenes of nature.

9. Air is likewise the medium of sounds. In consequence of its elasticity and undulating motion, it conveys to us knowledge and enjoyment of different kinds, which cannot be conveyed to the organs of sight, of taste, or of smell. A few strokes on a large bell will, in the course of a few seconds, by the undulation of the atmosphere, reach the ears of a hundred thousand men, and convey intimations either of joy or of terror. The sounds produced by the undulations of the air may be considered as so many couriers running backwards and forwards, and in every direction, to warn us of danger, to inspire us with joy, and to communicate various delightful sensations. When we walk along the road, musing, and unapprehensive of danger, a mailcoach may be whirling on its rapid career, and just at our heels, ready to roll over us; but the air,

like a watchful friend, despatches a courier from a considerable distance to warn us that danger is approaching, and to remove to the path of safety. While we walk along the streets of London, and other cities, we are continually in danger of cabs, coaches, drays, and other vehicles, rolling upon us; and were it not that the air, by its undulations, gives us timely notice of their approach, the accidents from this cause which occasionally occur, would be much more numerous than they now are. To this property of the air, we owe all the advantages we derive from hearing sermons and lectures, and all the pleasures we enjoy from friendly and instructive conversation. By means of the tongue and the lips we form articulate sounds, which, by the previous consent of mankind, become the signs of certain ideas; these sounds are conveyed to the ears of our friends, and inform them of the thoughts and ideas that were previously passing through our minds, and their understandings and hearts become impressed with the same sentiments. Without the ministration of the atmosphere in such cases, all would be sullen and unmeaning listlessness and silence, as in the intercourse of the deaf and dumb. So that the air may be considered as the cement of society—the medium of communication between one mind and another, and the interpreter of the thoughts and purposes of mankind.

To the same cause, we are indebted for all *the pleasures* and harmonies of music. Music

is one of the purest and most refined of our sensitive pleasures. It possesses the power of charming our ears, soothing our passions, and affecting our hearts; it dissipates the gloom of melancholy, animates the vital spirits, and gives sublimity to our thoughts and sentiments. When a lady tunes her melodious voice, or touches with her fingers the keys of the pianoforte, or the strings of the lyre, the air distributes every musical variation and every note, with the utmost precision. It conveys its message with the greatest impartiality to the ear of every listener. Though many instruments may be employed, and a thousand persons be present, and placed in every direction, it distributes the harmony alike to every ear. It keeps the most exact time—it conveys the slightest inflections of the voice, and the smallest variation of a tone. It runs through the whole compass of music, swells the sounds, and makes them even thunder in our ears. The next moment, it makes them flutter and melt into dying strains. After this, it swells the notes again, and sinks them in their turns. Thus it expresses, in the most lovely manner, every passion and emotion of the soul, and charms every heart with its persuasive sounds.

That all the effects now stated are owing to the ministration of the atmosphere, is proved by one decisive experiment. Place a small bell under the receiver of an air-pump; let it be rung, and the sound will be heard at a

considerable distance. Exhaust the air from the receiver, and the sound can scarcely be heard by the nicest ear. Even in places where the air is not excluded, but only highly rarefied, as in the higher regions of the atmosphere, sounds are scarcely heard. Fredlichius, a gentleman of Hungary, informs us, that when he was on one of the loftiest tops of the Carpathian mountains, he fired a pistol, which at first made no greater noise than if he had only broken a stick or a staff; but after a little time there was a murmuring for a while which filled the valleys and woods below. Descending to the lower valleys and the rugged rocks, he fired again, which made a dreadful sound, as if great guns had been discharged, and as if the whole mountain had begun to tumble about his ears. The sound lasted for half a quarter of an hour, till it had reached the most secret caverns, where the sound was enlarged and reflected back in every direction. These facts show that the elasticity of the air, which is always greatest where the air is densest, is essential to the propagation of sound.

10. The atmosphere is the cause of that splendour and universal light around us, which lays open to our view the landscape of the world. Were this atmosphere destroyed, we might see the sun without enjoying the light and brilliancy of day. That luminary would, indeed, strike our eyes with a vivid brightness when we turned round to behold his flaming *orb; but it* would appear only as a blazing

fire during night in a spacious plain, where all is gloom and darkness around. It would suddenly burst on our view in the eastern horizon, in the morning, and would not change its aspect in the least, during its course through the heavens, till it suddenly disappeared in the western sky. The objects immediately around us would be partially visible; but the rays of the sun which fell on distant objects would be for ever lost in the expanse of the heavens; and when we turned our back to the sun, nothing would present itself, but an abyss of darkness, and the whole horizon involved in a dismal gloom. The number of objects in the heavens would, indeed, be augmented, for the stars would shine through a canopy as black as ebony, even when the sun was above the horizon; but all the gay colouring of the terrestrial landscape, which now delights the eye and the imagination, would be for ever veiled from the inhabitants of the world. In such a state of things, it would be always night; and the difference between such a night and that which we now enjoy, would be, that the celestial orbs, instead of being grounded on a beautiful azure sky, would appear on a black canopy, like so many white points on a dismal mourning carpet.

But the Almighty, whose arrangements have all a respect to the happiness of his creatures, has enveloped our globe with an atmosphere, and has endowed it with a capacity of reflecting and refracting the rays of light in all directions.

This atmosphere, too, is charged with innumerable myriads of watery particles, exhaled by evaporation from every region of the sea and land. In the serenest days of summer, when no clouds nor vapours are to be seen, these rarefied particles of water, which are imperceptible to the keenest eye, fill the whole sphere of the atmosphere around us, both above and below the region of the clouds. It is among these rarefied waters in the higher regions of the air that the rays of light reflected from the surface of the land meet, and are again reflected in every direction to the earth; and hence is produced that beautiful azure colour which distinguishes the aspect of the heavens. This azure is sometimes lighter, according to the quantity of rays which enter the atmosphere, and sometimes darker, when the absence of the twilight heightens the blue of the celestial concave, by means of that black and void space which lies beyond the limits of the atmosphere. In corroboration of these remarks, it may be noticed, that the higher we ascend above the surface of the earth, the darker does the sky appear. And hence all travellers affirm, that, on the tops of lofty mountains, it sometimes appears as black as ebony, which causes the milky way to appear like a pure flame shot across the heavens, and the stars to shine with a greater brightness, and to appear far more numerous than in the plains below.

11. The atmosphere is the cause of the *morning* and evening twilight. We all know

that the day is gradually ushered in after the darkness of the night. More than an hour before the rising of the sun, in this part of the world, a streak of light appears in the eastern horizon. This light increases in brilliancy every moment—the landscape of the earth, which had been previously covered with a mantle of blackness, appears gradually to emerge from an abyss of darkness, like the light at the first creation—the circle of the horizon becomes inflamed with a bright vermilion—the mountain tops are tinged with purple; and at length appears the most beautiful and sublime object in nature, the sun rising in his might and glory. And, when this luminary has described the circuit of the heavens, and passed the verge of the western horizon, darkness does not come on instantaneously, but by slow and imperceptible degrees, so as to warn us to prepare for its approach. The season of twilight, particularly that of a summer evening, is perhaps one of the most agreeable and interesting periods of the day. How many delightful walks and excursions—how many cheerful and solemn musings—how many endearing intercourses of love and friendship does it recall to our recollection, when we strolled along the solitary walks, or reclined in the bower of friendship, till the rising moon and the twinkling stars called us to our nightly repose!

Now, all such pleasures and advantages derived from the twilight, are owing to the agency of the atmosphere. When the sun

approaches in the morning within eighteen degrees of the horizon, his rays strike obliquely on the higher parts of the atmosphere, and, instead of passing directly forward, they are refracted, or bent a little downwards, and thus descend by inflection to the earth. In this way we reap the benefit of those rays which would otherwise have been totally lost, and enjoy the light of day for a considerable time before the sun reaches the horizon. It is owing to the same cause that the sun is visible several minutes before he is actually above the horizon in the morning, and after his setting in the evening. This increases the length of every day, about $6\frac{1}{2}$ minutes at an average, which amounts to $3\frac{1}{2}$ equinoctial days in a year, and nearly a whole year's sunshine in the course of a century. And, if we reckon an hour and a half of twilight in the morning and as much in the evening, at an average, through the different seasons, we have more than ninety equinoctial days of twilight throughout the year. This is a circumstance of the utmost importance to those who inhabit the polar regions; in consequence of which, the inhabitants of Nova-Zembla and of Greenland enjoy the direct light of the sun for thirty-two days while he is under the horizon, besides the long twilight which precedes his rising, and continues after his descent below the horizon. But what would be the consequences if we had no twilight? Not only should we be deprived of the advantages now stated, but subjected to many incon-

veniences and dangers. Should the day break in upon us all at once in meridian brightness, immediately after the dark shades of night, our eyes would be dazzled, and in danger of being blinded by its excessive splendour. Should the night rush on in the same precipitate manner, and hurry us in a moment from the splendours of day to the horrors of midnight, it would strike the living world with amazement. The traveller would be arrested in the midst of his journey, and bewildered with terror; and if the sky were then covered with clouds, the darkness would be so thick and black, that not the least glimmering ray would strike across the universal gloom, nor a single object be perceived, even within the distance of a foot. Man would then appear as if he were placed without an object near him, in the midst of infinite space—

> ——"Dark as was chaos, ere the infant sun
> Was rolled together, or had tried his beams
> Athwart the gloom profound."

These arrangements, then, by which light is reflected over the face of nature, and twilight is produced, evidently show the wisdom and intelligence of the Almighty Creator, and his benevolent regards to his sensitive and intelligent offspring. A few small bubbles of air and water appear very insignificant to the eye of man. But in the hand of the Almighty they work wonders of love and beneficence. He has distributed them over our heads in every direction with so much caution and skill, in

order that the light of his sun and his stars might not be rendered useless to the world. With these invisible particles of water and air, he enriches and embellishes whatever he pleases; and in his hands they become an inexhaustible source of glory and happiness. From these insignificant atoms, he fetches the brightness of the aurora, and draws forth those twilights which lengthen our days, and prepare our eyes for receiving the brightness of the meridian sun. From these he produces the splendour of day, which the sun itself could never procure us. He makes them contribute to the preservation of that heat which nourishes the vegetable kingdom, and which is essential to the comfort of "everything that lives." Of them he has formed that magnificent arch which surrounds us on all sides, which enchants the eye of every beholder, and forms the canopy of our terrestrial habitation; for it is the light reflected from the air, and the innumerable particles of vapour it contains, which produces that beautiful azure which adorns the vault of heaven. This azure canopy the Creator might have painted with a darker hue, or even made it entirely black. But black is a sad and dismal colour, which would have thrown a melancholy gloom over the face of nature. A deep red would have been almost as disagreeable and hurtful to the sight; a white colour, by its excessive glare, would have been offensive to every eye, and would have *prevented* the light of the planets and stars

from being distinguished. A yellow would not have been quite so unsuitable; but this colour was reserved for the aurora which adorns the sky before the rising of the sun. Besides, a whole arch of a yellow colour would not have presented a sufficient contrast to the light of the celestial luminaries. The green, which is a pleasing colour to the eye, would have formed a better ground for the light of the stars; but it is with this lovely colour that the Almighty has adorned the surface of our earthly abode, and has spread it as a carpet under our feet; and it was necessary that there should be a contrast between the colour of the earth and of the sky, in order to complete the beauty and the magnificence of the scene of nature. The blue is, on the whole, a mild and pleasant colour, without any gloom or sadness in it; and while it forms a contrast to the verdure of the fields, it has the additional merit of forming a proper ground on which luminous bodies may be seen, and thus heightens the lustre and beauty of the stars.

In such admirable arrangements we cannot fail to perceive the marks of intelligence and skill, in causing an assemblage of invisible atoms to produce so many sublime and beneficent effects; and we must be void of gratitude, if we do not recognise the hand of Divine goodness in adorning our habitation with so many beautiful contrasts, and rendering every scene of nature subservient to our convenience and delight.

12. The transparency of the atmosphere is not the least of its advantages. It is not, indeed, perfectly transparent, otherwise it would not reflect the blue colour of the sky, nor would the distant mountains appear bedimmed and tinged with purple. But it has such a degree of transparency, that every object on the terrestrial landscape, within a reasonable distance, can be distinctly perceived. Even objects at the distance of a hundred and fifty miles, are visible through the air; and the telescope, though it magnifies the aërial particles, can make objects, at the distance of twenty miles, appear as if they were placed at the distance of three hundred yards. Were the air tinged with the least degree of yellow, red, or green, it would give the same colour to every other object, just as a stained glass makes every object seen through it appear of the same colour as itself. Were its particles much larger, and more opaque than they now are, so as to become perceptible to the eye, we should never obtain a distinct view of any other object. We should then see the air and the exhalations rising from the surface of the earth continually before us, like the particles of dust in a darkened chamber, when the rays of the sun are admitted through a small hole.

But the Almighty, by rendering the air invisible, has enabled us, in the first place, to take an extensive and delightful view of his wonderful operations in heaven and earth, and *of all the* objects which immediately surround

us—and, in the next place, has concealed from our eyes those objects which would have excited disagreeable sensations, and even disgust. If the air, like all other bodies, were an object of sight, the exhalations from the earth and waters would be much more easily discovered. The smoke of our chimneys, still remaining visible as it ascended, would disfigure the rich landscape of the world, and obscure the canopy of heaven. We should perceive all those gross humours which an incessant perspiration drives out of the bodies of all animals, and all the filthy exhalations that rise from kitchens, dunghills, stagnant marshes, streets, and common sewers. We should be apt to imagine our situation both unsafe and contagious, unless we fled into deserts and mountains, to avoid those incessant annoyances which would be the unavoidable result of such a visibility of the air and its exhalations. At the same time, lest these vapours should prove injurious to us, through their invisibility, the good providence of God has forewarned us of such danger, by imparting to us the sense of smell, and has also appointed the winds to disperse such nuisances, to carry them aloft, and to serve as the ventilator of the atmosphere; for, by the sense of smell, we are enabled to perceive when we are within the range of pestilential effluvia; and the winds seldom permit the air to remain in a stagnant state, provided our habitations are so arranged as to be within the sphere of their influence.

If we wish to feel grateful to the Supreme Disposer of the universe for the blessings of that world in which he has placed us, it is requisite that we should frequently fix our attention on such circumstances as those now stated. We pass from one day to another, and frequently from one period of human life to another, without reflecting on those admirable contrivances which appear in every surrounding object, by which our comforts are secured, and the universe rendered a spectacle of beauty and grandeur. Because we have never yet contemplated a world in confusion and ruins, we are apt to imagine that the arrangements around us could not be otherwise than they presently are. But, were that Being who created the atmosphere to make only a very slight alteration in its constitution—were he just to alter two apparently insignificant circumstances —were he to deprive it of its refractive and reflective powers—and were he to render it visible by tinging it with any colour, all other things remaining as they now are—immediately the scene of nature would be divested of all its beauty and magnificence—and this earth, which now cheers so many millions of animated beings with its comforts and embellishments, would be transformed into a scene of misery, an abode of darkness and desolation.

13. Were the atmosphere capable of being frozen, or congealed into a solid body, the most disastrous consequences would immediately *ensue*. All other fluids with which we are

acquainted are subject to congelation. Even spirits of wine, which long resist the influence of cold, and are, therefore, used in our thermometers, have been converted into a solid mass, by the cold of northern regions; and quicksilver, which is naturally a fluid substance, has been converted by cold into a compact body, capable of being hammered like a piece of lead. Nay, even some of the gases, or aërial fluids, show a disposition to congeal by a reduction of temperature. The oxygenized muriatic-acid gas becomes concrete, and forms into crystals, at a temperature near to that at which water freezes. All the gaseous substances, when they have lost their elasticity, by forming certain combinations, are disposed to assume the solid state, if the temperature allow it. Ammoniacal gas, and carbonic-acid gas become solid, as soon as they enter into combination; and hydrogen gas, the most subtle of the ponderable elastic fluids, forms, along with oxygen, that very water which is afterwards congealed into ice. What is the reason, then, that the atmospheric air which we every moment breathe, is not subject to congelation? We know no other reason but the will of the Creator. Were we thoroughly acquainted with every particular respecting the nature of the gases of which it is composed, and the mode of their combination, we might, perhaps, discover the physical cause of this singular property; but still, we should ultimately have to refer it to the Divine purpose and will that such a

cause existed. We know that the vapours which are suspended in the higher regions of the atmosphere, are frequently congealed into hailstones of a considerable size, and were any large portions of the air around us to be congealed in a similar manner, it is easy to foresee what disastrous effects would quickly be produced; and were the whole atmosphere to be frozen into a solid body, destruction would inevitably seize upon all the tribes of the living world, and the beautiful face of nature we now behold, would be transformed into a chaos.

Such is the intimate connexion that subsists between every part of the system of nature, and such is the exquisite mechanism with which all its parts are constructed and arranged, that if a single wheel or pinion of this vast machine were either wanting or deranged, the whole system would soon be dissolved, and fall into ruins. But that Almighty Being who sits on the throne of the universe, presides over all its subordinate movements, preserves every element in its respective station, and directs the apparently jarring principles of nature to accomplish his wise and benevolent designs.

In fine, we may just further remark, that man has acquired a certain degree of sovereignty over the atmosphere, by which he renders it subservient to his comforts, and to the execution of his designs. He causes it to sigh in the pipe, to complain in the flute, to thunder in the trumpet and the gong, and to utter a thousand melodious strains in the piano-

forte and the organ. He causes it to announce tidings of joy or sorrow. He forces it to grind his corn, to blow his furnaces, to winnow his grain, to raise water from the deepest pits, and to extinguish the flames when his buildings are on fire. He compels it to act as a prime mover in an endless variety of machinery, and, by its agency, in combination with other powers, ten thousands of wheels and pinions are daily set in motion—power-looms are weaving fabrics of various descriptions—spinning-jennies are set in action, steam-vessels impelled along rivers, and across oceans—and railway trains carried forward in every direction with the most rapid motions. He yokes it to his ships, and compels it to expand the sails, and to waft him across the billows of the ocean to the remotest shores. And, in short, it is on the wings of the atmosphere that he raises himself, with his balloons, above the mountain-tops, looks down from on high on the dusky earth, and ranges at large through the region of the clouds.

Thus, a few of the beneficial effects produced by the atmosphere in the system of nature, have been briefly stated. Its influence is essential to the germination and growth of plants, to the preservation of water in a state of fluidity, to the existence of fire and flame, to the respiration of all kinds of animals, to the process of evaporation, and the production of rain and dew; to support the clouds, and to give buoyancy to the feathered tribes. It is the

region of winds—the vehicle of smells—the medium of sounds, and the source of all the pleasures we derive from the harmonies of music; it is the cause of that universal light and splendour which are diffused around us, and of the advantages we derive from the morning and evening twilight; and all these advantages are more fully secured by the transparency of its particles, and by its being rendered incapable of being congealed into a solid body.

What, then, would be the consequences were the earth to be divested of its atmosphere? Were the hand of Omnipotence to detach this body of air from our globe, and could we suppose living beings at the same time to exist, the landscape of the earth would be disrobed of all its vegetable beauties, and not a plant nor flower would be seen over the whole face of nature; the springs and rivers would cease to flow, even the waters of the mighty deep would be dried up, and its lowest caverns exposed to view, like frightful and hideous deserts. No fire nor heat would cheer the abodes of man, either by day or by night, no rains nor dews would refresh the fields, no gentle zephyrs would blow, nor aromatic perfumes be wafted from blooming flowers. The birds would no longer wing their flight on high, nor would their warblings be heard among the groves. No sound whatever would be heard throughout the whole expanse of nature, universal silence would reign undisturbed over the world, and the delights of music

be for ever unknown. The morning would no longer be ushered in by the dawn, nor the day protracted by the evening twilight. All would be gloom and obscurity by day, except in that quarter of the heavens where the sun appeared, and no artificial light nor flame could be procured to cheer the darkness of the night. The whole surface of the globe would present one wide prospect of barrenness and desolation, without a single object of beauty to relieve the horrors of the scene; and this earth, which now presents to the beholder so many objects of sublimity and beauty, would appear as if it had sunk into the primitive chaos whence it arose. But, as we are certain that, according to the present economy of the animal system, no living creatures could exist in such a state of things, it would be an inevitable consequence of the annihilation of the atmosphere, that all the myriads of living beings which now people the waters and the earth, would sink into remediless destruction, and the great globe we inhabit be transformed into one immense sepulchre, without enjoyment, motion, or life.

If, therefore, the Creator had not a regard to the happiness of his sensitive and intelligent offspring—or, if he wished to transform this globe into an abode of darkness and a scene of misery, he has only to support the functions of animal life on a new principle, and then to sweep from the earth the atmosphere with which it is now environed, and the dismal catastrophe is at once accomplished. Such a consideration shows

us the propriety and the emphasis of the language of Inspiration, "In Him we live, and move, and have our being"—"In his hand is the soul of every living thing, and the breath of all mankind." But since we are assured that "the Lord is good to all: and his tender mercies are over all his works," and as we find no arrangement in the system of the universe whose ultimate object is to produce pain or misery to any sensitive being, we have no fear that such a catastrophe will ever be permitted to take place. At the same time, we know not what the great ends of his moral government may incline the Deity to perform. We know that, at one period, the system of nature connected with this globe was disarranged on account of the wickedness of its inhabitants, and a deluge of waters overwhelmed all the abodes of men. This catastrophe changed the aspect of the earth and atmosphere, and produced convulsions which shook the foundations of the earth, and disrupted its solid strata; the vestiges of which are still visible in every land, and form some of the subjects of scientific investigation. And, therefore, were the inhabitants of the world ever again to rise to the same pitch of wickedness as they did before the flood, we know not but the Almighty, instead of covering the earth with an abyss of water, might detach from it the surrounding atmosphere, and leave its inhabitants to the effect of such an awful catastrophe.

We learn from Revelation, that a period is

approaching, "when the elements shall melt with fervent heat, the earth also, and the works that are therein shall be burned up." In the hand of Him who sits on the throne of the universe, the atmosphere is fitted to become the means of producing this tremendous event. The atmosphere, as formerly stated, consists chiefly of two fluids, or gases, of very opposite qualities; one of these, namely oxygen gas, is the principle of combustion, and forms about one-fifth part of atmospheric air; the other, namely nitrogen, instantly extinguishes every species of fire or flame. Were the nitrogen, then, which forms four-fifths of the atmosphere to be swept away, and the oxygen left to exert its native energies, all the combustible substances on the face of the earth would instantly take fire, nay, the hardest stones, the most solid rocks, and even water itself, would blaze under its force with such energy as to carry destruction throughout the expanse of nature. Such are the elementary principles in the hand and under the superintendence of the Almighty, which are ready at his command to bring into effect all the events, changes, and revolutions, in relation to our world, which are predicted in the word of Divine Revelation.

CHAPTER VIII.

The wisdom and benevolence of the Creator, as displayed in the constitution of the atmosphere.

As this topic has been partially alluded to in the preceding chapter, only two or three additional illustrations may now be given.

1. The wisdom and goodness of God are manifest, in the proportion which subsists between the different gases of which the atmosphere is composed. Were the oxygen less in quantity than it now is—were it, for example, in the proportion of fifteen to eighty-five, a hundred parts of nitrogen, instead of twenty-one to seventy-nine, fire would lose its strength, candles would not diffuse a sufficient light, plants would wither, and animals could not breathe without the utmost difficulty and pain. On the other hand, were the nitrogen diminished, and the oxygen greatly increased, the least spark would set combustible bodies in a flame, and, in a few moments, they would be entirely consumed. Candles would be wasted in a few minutes after they were lighted, and would serve no other *purpose* than to dazzle our eyes with a tran-

sient blaze. Were a few houses in a large city set on fire, such would be the rapidity with which the flames would spread on every side, that in a few hours, or even minutes, the whole city would be wrapped in one wide and unquenchable blaze, and no human art could arrest the progress of the destructive conflagration. In such atmospheric air, iron would be calcined, instead of acquiring from the fire that softness necessary for forming it into various instruments; it would accelerate to a dangerous degree the circulation of the fluids in animal bodies, and produce a degree of heat through the influence of which they would rapidly waste and decay. We know by experience that nitric oxyde, which consists of forty-four parts of nitrogen and fifty-six of oxygen, produces instant suffocation in all animals that attempt to breathe it. We also know that the nitric acid, one of the most corrosive substances, is composed of seventy-five parts oxygen and twenty-five parts nitrogen, which are only different proportions of the substances in atmospheric air; so that were the atmosphere composed of the same proportion of ingredients, our breathing it might produce the same effect as if we were to swallow a pint of aquafortis, or nitrous acid, which we all know would produce our immediate destruction. Can we, then, be at a loss to perceive, in the adjustment of the gases which compose our atmosphere, the wisdom and benevolence of the Deity; and, at the same time, the infinite comprehension of the Divine

Mind, in foreseeing all the effects that would be produced by the different combinations of these gases, and in selecting that particular combination for the atmosphere which is precisely adapted to the existence and the comfort of living beings?

2. The Divine wisdom and goodness are no less conspicuous in determining the relative specific gravity of these gases. The oxygen gas is found to be a little heavier than common air, and the nitrogen a little lighter, which enables it to rise to the higher regions of the atmosphere. In respiration (or breathing) there are four stages or periods:—1. Inspiration, or drawing in the air.—2. A pause when the lungs are filled.—3. Expiration, or breathing out the air from the lungs;—and 4. A pause when the lungs are emptied. In breathing, the air which is evolved from the lungs at every expiration, consists chiefly of nitrogen, (and a small portion of carbonic-acid gas,) which is entirely unfit to be breathed again, and, therefore, by its levity, rises above our heads before the next inspiration. The pause which takes place between every inspiration is evidently intended to allow time for the nitrogen gas which is thrown out of the lungs to rise in the air, in order that a fresh portion of the atmosphere may be taken in, and that the same air may not be breathed again. During that remarkable interval, there is time left for the *nox*ious fluids to separate, the nitrogen to ascend *while* the carbonic-acid gas preponderates,

leaving a space between for a fresh current of pure atmospheric air to rush into the lungs. But what would be the consequence if nitrogen gas, instead of being a little lighter, had been a slight degree heavier than common air, or of the same specific gravity? Then we should not only have been obliged to breathe a portion of it again at every inspiration, but the vast quantity of it thrown off by the respiration of men and other animals would have perpetually occupied the lower regions of the atmosphere; and especially in our chambers it would have accumulated to such a degree as to have produced diseases, pestilence, and death, in rapid succession. But, being a little lighter than the surrounding atmosphere, it flies upwards, and we never breathe it again till it has entered into new and salutary combinations. Such is the benevolent skill which the great Author of nature has displayed for the preservation and comfort of the human race, and of every species of animated existence.

3. The wisdom of the Creator is displayed in the process for supplying the waste of oxygen, and promoting the renovation of the atmosphere. The quantity of carbonic acid which is daily formed, by combustion and the respiration of animals, is so great, that it must have rapidly increased to a most dangerous extent, had not the Almighty provided means for its being as rapidly decomposed. It is well known that whenever atmospheric air becomes charged with one-tenth of this gas, it is unfit for

promoting combustion, and is fatal to most animals that breathe it. Hydrogen too, and carburetted hydrogen gas, are perpetually evolved at the surface of the earth from various sources, particularly from marshes, dunghills, and stagnant pools; and these are likewise prejudicial, and even destructive, to the animal creation. On the other hand, oxygen gas, which is the support of fire and animal life, is continually wasted by the various processes of combustion, as in the case of furnaces, burning candles, and domestic fires, and by the breathing of all animals. How, then, has the all-wise Creator contrived to supply this waste, and to protect the inhabitants of the world from the baneful effects of the other gases with which the atmosphere is contaminated? The process appears to be this:—Vegetables are so constituted that carbon and hydrogen are the necessary food of plants, and are conducive to the support of vegetable life. Their vegetating organs seize the carbonic-acid gas that comes within their reach, and while they appropriate the carbon to themselves, the oxygen is thrown off to renovate the atmosphere, by its union with the nitrogen ejected by animal respiration. The leaves of trees, shrubs, and other vegetables, give out, during the day, a large portion of oxygen gas, which unites with the surrounding air, keeps up the equilibrium of the gases, and preserves the salubrity of the atmosphere; for it is found by experience that the air in every *region, in* the most crowded cities, as well as

in the open fields, contains the same quantity of oxygen gas. Thus it appears, that what is noxious to man is rendered beneficial to the vegetable tribes, and the oxygen of which they do not stand in need, is separated by them, in its utmost purity, for the use of man. The wisdom, the simplicity, and the beneficence of this arrangement, cannot fail to produce conviction in every reflecting mind, that the laws of nature are not to be referred to blind chance, but to unerring intelligence combined with boundless beneficence. In every breath we draw, we may perceive, if we reflect on the above-stated arrangements, that we are every moment indebted to an all-wise and almighty Being in whom we live and move, for the continuance of our existence and for every comfort we possess, and therefore praise, adoration, and thanksgivings, are due to him from all the ranks of his intelligent offspring.

The department of the subject already treated, may now be concluded with a reflection or two, founded on the statements previously made.

1. From the invisibility of the atmosphere, and its numerous and important effects in the system of nature, we may learn the folly of denying the reality of a future and invisible state of existence, because the objects connected with that state are not perceptible by our corporeal senses. Who could have imagined, previously to modern discoveries, that all the

functions of the vegetable kingdom, and all the comforts enjoyed by animated beings, are dependent upon the operation of a few invisible fluids, and that all the beauties of this lower creation are owing to the composition and decomposition, in a thousand different ways, of those gaseous substances whose operations are imperceptible to the keenest eye? And yet, the researches of modern chemistry have proved this fact to a demonstration, and shown us that every breath we draw, every pleasing sensation we feel, every portion of food we eat, every particle of heat that warms our apartments, every ray of artificial light that illuminates our streets and habitations, and every musical sound that enchants our ears, are owing to the unremitting motion and energy of invisible substances. And shall we, then, assert that the invisible principle of mind is not in existence or in action beyond the limits of this diurnal sphere, because its operation in that state lies beyond the range of our senses? We behold multitudes of rational beings daily departing from the living world; their organical frames crumbling into the dust, and the intellectual principle which animated them disappearing from mortal view. But we have no more reason to doubt that it is existing and operating in another sphere, than we have to doubt of the incessant energy of the invisible gases in giving life and beauty to sublunary nature. The disembodied spirits of men, *whether* existing in a pure ethereal form, or

invested with fine material vehicles, may be employed in active services, and in sublime contemplations and investigations, of which we can at present form no adequate conception. We may, on the same grounds, form a conception of spirits suffering pains, anxieties, sorrows, and miseries, of different kinds, from a retrospective view of their former feelings, affections, and conduct, even when separated from those material organs with which they were formerly connected.

With regard to the great objects of religion, many of them lie beyond the range of our corporeal vision, as some of the agents employed in certain chemical processes elude our senses. Faith is described to be "the confident expectation of things hoped for, and the conviction of things which are not seen."* It substantiates and realizes those objects which are invisible to the eye of sense, or which lie far beyond its present range of view. Hence we are told that, in the present world, we should "walk by faith, not by sight." The objects connected with a future world are real, although they are placed at such a distance as not to be cognizable by our present visual organs. They are not all merely of a spiritual nature, they are also connected with material objects; but, between our sensitive organs and such objects, immeasurable regions of space intervene. The glorified body of the Redeemer of mankind is a material substance and an object of sense,

* Doddridge's Translation of Hebrews xi. 1.

and it inhabits a region somewhere within the bounds of the material creation, but its distance from the sphere in which we now reside removes it from our view; and we want that vigour and energy of our corporeal organs which the martyr Stephen seems to have enjoyed, when the heavens were opened, and "he saw the glory of God, and Jesus standing on the right hand of God."

In certain pools of water, animalcules are found, whose bodies, when magnified a hundred thousand times their natural size, are visible only as so many moving points. A considerable portion of the watery element on our globe is filled with such invisible inhabitants, which have never been perceived by the millionth-part of mankind. In this and similar instances, we have an invisible world of animated beings existing around us, but no one calls in question their existence because they can only be observed by powerful microscopes, and are not perceptible by the majority of mankind. In short, the Divine Being pervades every part of space with his essence, and is intimately present with every one of his creatures, yet remains for ever invisible to mortal eyes. But, on this ground, no one but an atheist ever calls in question his existence. In like manner, the invisibility of the objects connected with a future world ought to form no ground of doubt respecting the certainty and reality of their existence.

2. We may learn what ought to be our great

object in the study of the sciences, and in the investigation of the phenomena of nature.

Some persons are disposed to consider science and natural history merely as genteel studies; others apply their minds to such subjects with the view of bearing a part in the conferences of men of learning. Some, again, prosecute such pursuits for the purpose of making collections of scarce and valuable curiosities, and of displaying a degree of knowledge and taste superior to those of their neighbours; and the greater part of mankind consider such studies as only an amusement, or a relaxation of mind from the fatigues of their daily avocations. But the study of nature and of science is highly dishonoured by such grovelling and contracted views. The prospect of the universe was exposed to our view for more noble and exalted purposes—to make us wiser and better men, to expand our views of the perfections of our Creator, and to inspire us with a grateful sense of all the blessings we daily receive from his bountiful hand.

There are two great objects which we ought always to keep in view in our investigations of the laws of nature and of the principles which operate in the material world. In the first place, to deduce from our observation of physical facts, those principles by which the powers of man may be extended—the useful arts improved and carried to perfection—and the comforts and enjoyments of mankind promoted and increased. In the next place, and

chiefly, that our conceptions of the Creator's power, wisdom, benevolence, and superintending providence, may be enlarged, and that we may be more disposed to pay him that tribute of adoration and gratitude which is due to his name. Every study which sets the supreme Being on one side and nature on the other, is nothing more than an idle amusement —it is lost labour, and productive of little else than ignorance and error, pride and arrogance. To employ our thoughts on a thousand particulars in nature without directing them to the great Creator of all things—to profess to admire the displays of his wisdom, omnipotence, and goodness, while we violate his laws, and persist in a course of avarice or of dissipation—to be conscious of the blessings we every moment receive, and, at the same time, to be utterly unmindful of the hand from whence they flow—are a most glaring inconsistency, a shameful abuse of our understanding, and an act of the most flagrant ingratitude. All our knowledge is of no farther importance to us than as it has an influence on our affections and conduct, and leads us to entertain impressive and reverential ideas of that almighty Being, "in whose hands our breath is, and whose are all our ways."

Let us, then, for the air we breathe, and the numerous benefits we derive from the surrounding atmosphere, display our gratitude, and consecrate all our powers and faculties to *the service* of Him who "made the earth by

his power," and "hath established the world by his wisdom;"—who "causeth the vapours to ascend from the ends of the earth;" who "maketh lightnings with rain, and bringeth the wind out of his treasures," and whose "tender mercies are over all his works." To Him who hath created and redeemed us, all our powers and energies ought to be devoted from henceforth and for ever, for he is worthy to receive all praise, honour, and dominion from men, from angels, and from the inhabitants of all the worlds dispersed throughout the regions of the universe.

PART II.

ATMOSPHERIC PHENOMENA.

THIS is a subject which would admit of illustration sufficient to occupy a distinct volume; but the present limits will admit of only a very condensed and superficial view of the diversified objects connected with the phenomena of the atmosphere.

The atmospherical phenomena may be arranged under the following heads :—

I. Aqueous meteors; as evaporation, rain, snow, hail, clouds, etc.

II. Winds, sea and land breezes, monsoons, hurricanes, etc.

III. Luminous and fiery meteors, as fire-balls, falling-stars, thunder and lightning, luminous arches, fata morgana, aërial spectres, etc.

CHAPTER I.

Aqueous meteors.

1. EVAPORATION.—This is a process by which water and other substances are converted into elastic fluids by the influence of heat or caloric.

Vapours, being lighter than air, are raised into the upper regions of the atmosphere, and afterwards, by a partial condensation, form those clouds which we see floating around us. They are elastic, invisible substances, like common air, but lighter; being to common air, according to Saussure's experiments, as ten to fourteen. If we expose water to heat, bubbles at first adhere to the sides of the vessel, which by degrees ascend to the surface and burst. These bubbles rise the more rapidly in proportion to the heat. Water is evaporated by the heat of the sun merely, and even without it in the open air; and the vapour rising into the air is condensed into clouds. An immense quantity of vapour is, in this way, raised from the different regions of the earth. In order to estimate the quantity thus raised, Dr. Watson, bishop of Landaff, made the following experiment:—Having provided a large drinking-glass, the area of the mouth of which was twenty square inches, he placed it with its mouth downwards on a grass-plat which was mown close. The sun shone bright and hot, and there had been no rain for upwards of a month. When the glass had stood on the grass-plat one quarter of an hour, and had collected a quantity of condensed vapour, he wiped its inside with a piece of muslin, the weight of which he had previously ascertained, and, as soon as the glass was wiped dry, the muslin was weighed. The medium increase of weight from various experiments, between twelve and three o'clock, was six grains

in one quarter of an hour, from twenty square inches of earth. At this rate of evaporation, computing seven thousand grains troy to one pint of water, and eight pints to a gallon, it may be shown that one thousand six hundred gallons of water would be raised from one acre of ground in twenty-four hours. It is evident that the quantity will be still greater when the ground has been drenched with rain. To prove this, the same philosopher made two other experiments, one of them the day after the ground had been wetted by a thunder-shower; and to ascertain the circumstances more exactly he took the heat of the earth by a thermometer laid on the grass, which in the first experiment was ninety-six degrees, when the evaporation was at the rate of 1,973 gallons from an acre, in twelve hours. The other experiment was made when there had been no rain for a week, and when the heat of the earth was 110 degrees; this experiment gave after the rate of 2,800 gallons from an acre in twelve hours; the earth was hotter than the air, being exposed to the reflection of the sun's rays from a brick wall.

Hence it appears that evaporation must form a very important process in the economy of nature. The following are some facts in relation to this process. A much greater quantity of vapour rises during hot weather than during cold, as appears from the preceding experiments. Even where the temperature is *the same*, it varies according to circumstances.

It is least of all in calm weather, greater when a breeze blows, and greatest with a strong wind. In our climate, the evaporation is about four times as great between the vernal and autumnal equinox as in the rest of the year. The degree of cold produced by evaporation is much greater when the air is warmer than the evaporating surface, than when the latter is the warmer of the two. From these and other facts, it is plain that tracts of land which are covered with trees are much colder than those where there is a less surface of vegetable matter, such grounds being found to emit one-third more vapour than the same space covered with water. Hence the important change of climate which a country undergoes by being cleared and cultivated. America is not the same country at present, either with respect to temperature or salubrity, as it was several centuries ago, when it was covered with woods.

By this perspiration of the globe, it has been estimated that thirty-six inches of water per annum are raised from the surface of all the seas and rivers, and at least thirty inches from all the regions of the land. Hence it follows, that by this constant process of evaporation, 100,000 cubic miles of water are, every year, raised into the atmosphere; the greater part of which, at a certain height, parts with its heat, and is condensed into clouds. Were this prodigious mass of water all to subsist in the atmosphere at once, it would increase about a twelfth part, and raise

the barometer nearly three inches. But this never happens; no day passing without rain in some parts of the earth, so that part of the evaporated water is again constantly precipitated. The clouds formed by evaporation are carried by the winds over the land, broken, and precipitated by the action of mountains and trees, and thus rendered the means of watering the soil, and producing fertility throughout every region of the globe. It is owing solely to this process that our clothes, when washed and spread out to the open air, are soon dried. Were there no such process as evaporation in the system of nature, our linens and other clothes, when drenched in water, might remain for centuries without being dried—a circumstance which is seldom thought of by thoughtless men, but which demands our thanksgiving and gratitude. Hence we are called upon by the sacred writers to praise "the name of the Lord," who "causeth the vapours to ascend from the ends of the earth," Psalm cxxxv. 5.

2. *Clouds.* — The aqueous vapours, condensed by cold, or rising in the atmosphere to a region of the air lighter than themselves, form strata of visible vapours, which we call clouds. These masses assume a great variety of shapes and configurations, which sometimes enliven the face of the sky, and at other times cause a gloom and shadow of darkness to overspread the landscape. The distance of the *clouds* above the surface of the earth varies at

different times, and according to the nature of the cloud. Thin and light clouds frequently rise to the height of four or five miles, as they are sometimes seen above the tops of the highest mountains. Their average height may be reckoned about two and a half miles; but some dense clouds frequently descend so low as to touch mountains, hills, steeples, and even high trees, particularly during thunder-storms. The size of some of these clouds has been estimated to cover a space of fifteen or twenty square miles, and their thickness above a thousand feet. Their motions are generally directed by the winds, excepting when thunder is about to happen; in which case, they seem to move very slowly, and sometimes remain absolutely stationary, which is probably owing to their being impelled by two opposite currents of air.

Clouds have been arranged by modern naturalists into several classes, according to their different configurations, and the regions of the atmosphere where they are generally found. They have been distinguished by Howard into seven modifications, the peculiarities of which are supposed to be caused by the agency of electricity. There are three primary modifications—the cirrus, the cumulus, and the stratus; two which may be considered as intermediate in their nature—the cirro-cumulus, and the cirro-stratus; one which appears to be a compound—the cumulo-stratus; and, lastly, the cumulo-cirro-stratus, or nimbus.

a state which immediately precedes the resolution of clouds into rain. These clouds are generally assigned to three atmospherical regions, the upper, the middle, and the lower one; to which a fourth, the lowest, may be added. In the upper region, the atmosphere is in such a state that it can receive and sustain only light and thin vapours, and to this district belongs the cirrus.

The cirrus has the least density of all the forms of cloud, but the greatest height and variety of shape and direction. It is the first indication of serene and settled weather, and first shows itself in a few fibres spreading through the atmosphere. It sometimes looks like a fine whitish thread pencilled on the clear blue sky. These fibres, by degrees, increase in length, and new fibres attach themselves to the sides. The duration of the cirrus is uncertain: in some kinds of weather, its figure is so rapidly and continually changed, that, after turning the eye from it for a few minutes, it will frequently be found almost completely changed. In other cases, it is sometimes visible for many hours and even days together, without much changing its appearance. From its usually curling appearance, this species of cloud is called the mare's-tail cloud.

The cumulus is a cloud of a dense structure, formed in the lower region of the atmosphere, and moving along in the current of wind which is next the earth. Its first appearance is *generally* a small irregular spot, which in-

creases in size, preserves a flat horizontal base, and assumes more or less of a conical figure. Such clouds are sometimes pretty well defined hemispherical masses; at other times, they rise into mountains, ranged in one plane, their silvery summits presenting a beautiful appearance. Before rain they increase very rapidly, and descend lower in the atmosphere. Great masses of them, during high winds, are seen in the quarter of the heavens towards which the wind blows, indicate approaching calm and rain.

The stratus has a mean degree of density; it is the lowest of clouds, and its inferior surface frequently rests on the earth or on the water. The time of its appearance is about sunset, and it disappears soon after sunrise. It comprehends all those creeping mists which, in calm evenings, ascend in spreading sheets, like an inundation of water, from the bottom of valleys. Sometimes it remains quiet, and accumulates in layers, till the atmosphere is capable of sustaining its weight, when it assumes the position of the dark nimbus, and falls in a shower of rain.

The other species of clouds may be briefly stated, which are compound modifications. The cirro-cumulus consists of a collection of small white clouds, of a roundish form, which give to the sky the appearance called dappled, and are, in summer, considered as a prognostic of settled weather; or, at least, of an increase of temperature. They form a very beautiful sky,

and are more frequent in summer than in winter. The cirro-stratus is generally in the form of long horizontal streaks, which are ever shifting their figure and position. It precedes wind and rain, the near or distant approach of which may sometimes be estimated from its greater or less abundance. It is frequently seen in the intervals of storms. The form and relative position, when seen in the distance, frequently give the idea of shoals of fish. It is that modification which most frequently exhibits the phenomena of the solar and lunar halo. The cumulo-stratus is a large, lofty, dense cloud, which may be compared to a mushroom, with a very thick short stem. It rises through the interstices of the superior clouds; and the whole, seen as it passes off in the distant horizon, presents to the fancy mountains covered with snow, intersected with dark ridges, rocks, towers, and other objects. Before thunder-storms, it frequently appears reddish. The nimbus is the cloud of rain. Before rain takes place, the clouds are uniformly found to undergo a change, attended with appearances sufficiently remarkable to indicate this as a distinct modification of clouds. It consists of a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally, and from beneath.

Clouds are frequently highly charged with electricity. These not only produce violent storms of thunder and lightning, but are sometimes the cause of the destruction of life and the most dreadful devastations. In the year

1772, a bright cloud was observed, at midnight, to cover a mountain in the island of Java, which emitted flames of fire so luminous, that the night became as clear as day. It destroyed everything for twenty miles around: buildings were demolished, plantations buried in the earth; fifteen thousand cattle, a vast number of horses and other animals, and above two thousand human beings, were destroyed by the agency of this tremendous cloud. On the 29th of October, 1757, in the island of Malta, a little after midnight, a great black cloud appeared, which changed its colour as it approached the city, till it became like a flame of fire, mixed with black smoke, and a dreadful noise was heard on its approach. It tore an English ship to pieces, and carried the masts, sails, and cordage, to a great distance. Small boats, in its course, were broken to pieces and sunk. In passing through the city, it laid in ruins everything in its way; houses were levelled with the ground, the roofs of churches were demolished; not one steeple was left in its passage, and the bells, together with the spires, were carried to a distance. In this awful catastrophe, the number of human beings killed and wounded amounted to nearly two hundred. Thus it appears that, while clouds serve occasionally as so many screens to abate the heat of the sun in warm countries, and form depositories of rains, which water and fertilize the earth, they are also sometimes used in the hands of the Almighty as instruments for the

infliction of his judgments upon the nations; for the clouds are his chariots, the thunder his voice, and he "walketh upon the wings of the wind."

3. *Rain.*—We have already stated that the waters of the earth, by evaporation, yield a certain quantity of moisture to the air, which, being condensed, assumes the form of clouds, floating at different distances above us in the atmosphere. Whatever suddenly disturbs the heat or density of the air, or the electricity of the clouds, occasions the particles of vapour to rush together, and form drops of water too heavy to continue suspended in the atmosphere; they fall in the shape of rain, and increase in size as they fall, by combining with the floating vapours as they pass through them. We have but an obscure conception, however, of the chemical nature of vapour, and of the chemical processes which are going on in the production of vapour, and its subsequent resolution into rain. Dr. Thomson has this general remark on the subject, after quoting the opinions of Dr. Watson, Dr. Hales, and others, that "the formation of clouds and rain cannot be accounted for by a single principle with which we are acquainted. It is neither owing to the saturation of the atmosphere, nor the diminution of heat, nor the mixture of airs of different temperatures; for clouds are often formed without any wind at all, either above or below them: and even if this mixture constantly took *place, the* precipitation, instead of accounting

for rain, would be almost imperceptible." Instead, therefore, of detailing conflicting opinions on this subject, we shall state only a few general facts in relation to rain.

It is worthy of our notice, that drops of rain are always found larger in the lower regions of the atmosphere. In going down a high mountain in the time of rain, the drops gradually increase, till, reaching the bottom, they increase from a drizzling shower to a heavy rain. To ascertain the generality of this fact, Dr. Heberden, in the year 1776, made the following experiment. He placed a rain-gauge on the square part of the roof of Westminster Abbey, another on the top of a neighbouring house, considerably lower than the first, and another on the ground, in an adjoining garden. The rain collected in each was as follows:—top of Westminster Abbey, twelve inches; top of the house, eighteen inches; and on the ground, twenty-two inches; so that more rain was collected in the lower than in the upper rain-gauge. The proportions of rain vary in different months of the year. In summer, we have not so many rainy days as in winter; but the showers are then heavier, the streams of rain closer together, and the quantity which falls is greater than during any other season. Dr. Dalton states that the first six months of the year may be regarded as dry, and the last six as wet months. From certain long-continued observations, it has been inferred that, in spring, it rains oftener in the evening than

in the morning; but that towards the end of summer, oftener in the morning than in the evening; and that storms at this time are apt to occur a little after sunrise. In the progression of the seasons, rain falls at all times during the twenty-four hours, but it has been ascertained that much less falls by day than by night.*

The annual quantity of rain is greatest in tropical countries, and diminishes as we approach the poles, owing to the greater evaporative qualities of the atmosphere in warm than in cold countries. Within the tropics, rain is not of the drizzling character of rain in the temperate zone, but generally falls in such torrents as in other zones would be called waterspouts, and they produce greater floods in a single day than in Europe in six days. Winter is distinguished from summer chiefly by the quantity of rain, which, for six months, is often constant for many days together, and lasts a certain number of hours per day. The rivers, in consequence, overflow, and in many countries produce inundations, which intercept all communications between neighbouring towns and villages. The mean quantity of rain which falls annually in England is thirty-two inches. In the western parts of Scotland, the depth is from thirty to thirty-five inches; in the eastern

* It is said, that on the 29th of October, 1827, there fell, at Joyeuse, in France, twenty-nine inches of rain in twenty-two *hours; and, in* eleven days, thirty-six inches; which is double *that at Paris* during the year.

parts, from twenty-four to twenty-eight inches. At Edinburgh, it is twenty-four inches and a half; and in London, twenty-two and one-fifth. There is more rain in the western parts of Britain than in the eastern, because these parts receive the first clouds as they are brought from the Atlantic by the westerly winds. In the West Indies, one hundred and twenty inches fall annually; and, in the East Indies, from eighty to one hundred inches. At Bombay, eighty-two inches, and at Calcutta, eighty-one inches fall annually.

When mountain-ranges, and other distant objects, appear nearer to us than usual—when sounds are heard more clearly from a distance—when the odour of plants is more than usually powerful, rain may be soon expected. Ducks, geese, and other water-fowls, before the approach of rain, may be seen to throw water, with their bills, over their heads. Cattle may likewise be seen stretching out their necks, and snuffing in the air with distended nostrils. Dogs, closely confined in a room, become drowsy and stupid before rain; the same is observed in cats, though in a less degree; horses neigh frequently; cattle low; the fallow-deer become restless; and swallows fly in a low course. Delicate persons are often affected before rain, with headaches, pains in old sores which have healed, irritability of temper, the aching of corns, and excessive nervousness. Several flowers and plants are prognosticators of rain. When the flower of the chickweed

closes, showery weather or continued rain may be expected. The trefoil, the convolvulus, and other plants, contract their leaves before the approach of rain. When the moon is of a pure silvery colour, good weather is indicated; but when it has a brownish tint, rain may be expected. When stars are surrounded with coloured halos, the approach of rain is indicated.

In the present constitution of our globe, rain —though sometimes attended with a few inconveniences—is essential for promoting the enjoyments both of man and beast. It moistens and softens the earth, and prepares it for being cultivated, and for affording nourishment to the vegetable tribes, which both adorn the landscape of the world, and afford nourishment to the human race and to every species of animated existence. By falling on high mountains, it carries down with it many particles of loose earth, which serve to fertilize the surrounding valleys, and purifies the air from noxious exhalations, which tend, in their return to the earth, to meliorate the soil. It moderates the heat of the air, and forms one of the sources whence fountains and rivers are supplied. Without the influence of rain, trees, shrubs, and flowers, would soon wither, sicken, and die, and every land be then turned into a barren wilderness. But when the clouds, at seasonable periods, pour down their watery treasures, all sublunary nature is invigorated and refreshed, and the vegetable productions of the

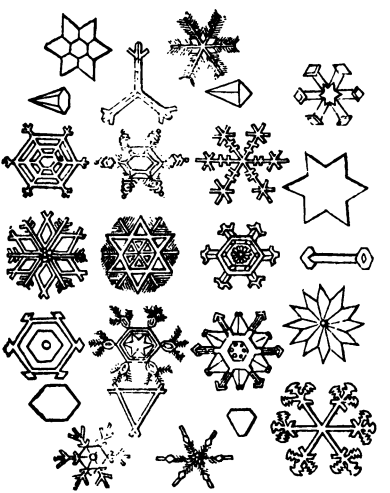
soil are made verdant and flourishing, and adorn the surface of the earth with their gay attire and diversity of colours. In the language of the Psalmist, "The little hills rejoice on every side. The pastures are clothed with flocks; the valleys also are covered over with corn; they shout for joy, they also sing." He who at first formed the earth for man, "watereth the ridges thereof abundantly," maketh it "soft with showers," blesseth "the springing thereof," and crowneth the year with his goodness. It is represented by the inspired writers as the peculiar prerogative of Jehovah to send rain upon the earth: "Are there any among the vanities of the Gentiles that can cause rain? or can the heavens give showers? Art not thou He, O Lord our God?—for thou hast made all these things." The effects produced by the want of rain is emphatically described by these writers: "Thy heaven that is over thee is as brass, and the earth that is under thee as iron." "The field is wasted, the land mourneth; for the corn is wasted. . . . Be ye ashamed, O ye husbandmen; howl, O ye vine-dressers, for the wheat and for the barley; because the harvest of the field is perished. The vine is dried up, and the fig-tree languisheth; the pomegranate-tree, the palm-tree also, and the apple-tree, even all the trees of the field, are withered. . . . How do the beasts groan! The herds of cattle are perplexed, because they have no pasture; yea, the flocks of sheep are made desolate; . . . for the rivers of waters are dried up, and the fire hath

devoured the pastures of the wilderness," Joel i. 10—12, 18, 20.

4. *Snow.*—Snow consists of such vapours as are frozen while the particles are small. It differs from hail and hoar-frost, in being crystallized, which they are not. When a flake of snow is examined by a magnifying-glass, the whole of it will appear to be composed of fine shining spicula, diverging like rays from a centre. As the flakes fall down through the atmosphere, they are continually joined by more of these radiated spicula, and thus increase in bulk, like the drops of rain or hail-stones. Many of the flakes of snow are of a regular figure, for the most part stars of six points, and are as perfect and transparent ice as any we see on a pond or river. Their forms present an almost endless variety, are often very regular and beautiful, and reflect, with exceeding splendour, the rays of the sun. When they are very large, they are said to indicate the approach of thunder. The different forms which the flakes of snow exhibit, when viewed through microscopes, are represented in figure 6. These crystals of snow are from one-third to one thirty-fifth of an inch in diameter, in their natural size. Experiments have been made, which prove that snow is twenty-four times lighter than water, and that it fills up ten or twelve times more space at the moment of falling, than the water produced from it, when melted. It is worthy of remark, *that previous* to the fall of snow, and during its

continuance, the temperature continues at about 32°. The lightness of snow, although it is

Fig. 6.



firm ice, is owing to the excess of its surface in comparison to the matter contained under it. Its whiteness is owing to the small particles into which it is divided; for ice, when pounded, will become equally white.

Snow is frequently formed in the lower regions of the atmosphere. A very cold stream of air admitted into a room in which the

contained air is much warmer, and loaded with watery particles, will occasion its formation. In the huts of those who inhabit the arctic regions, snow is frequently formed in this manner. Dr. Robertson states that, in a crowded assembly-room in St. Petersburg, a stream of cold air was accidentally admitted into the room by a gentleman breaking a pane of glass, on which the vapour in the air was immediately congealed, and fell in the form of snow-flakes. In Siberia, Nova Zembla, and other northern regions, the same phenomenon frequently happens. Snow occurs in all regions of the globe at a certain height above the level of the sea, but it falls more abundantly on plains as we proceed from the equator to the poles. In the arctic regions, snow falls nine days out of ten in the months of April, May, and June, and often to a depth of two or three inches in an hour. Among the mountains of Germany, Italy, and Switzerland, snow is sometimes accumulated to such an extent as to produce the most terrific and destructive effects, as in the case of the rolling avalanche. An avalanche is a mountain-mass of ice, or frozen snow, which is sometimes loosened from its base, and descends from the mountains with a force so terrible, that it crushes the traveller beneath its power, and buries hamlets and villages in a common grave. In the year 1749, the whole village of Rucras, in the canton of Grisons, in Switzerland, was covered, and, at *the same* time, removed from its site, by an

avalanche of this description. But this change, which happened in the night-time, was effected without the least noise, so that the inhabitants were not aware of it; and, on awaking in the morning, could not imagine why daylight did not dawn. A hundred persons were dug out of the snow, sixty of whom were still alive, the interstices between the snow containing sufficient air to support life. Not many years ago, an instance occurred of a family buried under one of these avalanches, and who continued in that situation for above a fortnight, remaining all that time in utter darkness, and incrusted in a body of snow several hundred feet in thickness. A massy beam supported the roof against this enormous pressure; and a milch ass, that happened to be thus incarcerated with the people, furnished sufficient nourishment for the support of life, till they were, at length, restored to the light of day.

The great Dispenser of universal bounty has so ordered it, that snow is eminently subservient, as well as all his other works, to his benevolent designs. As the winter cold is much more hurtful to vegetables than to animals, the plants would perish, if their roots were not preserved by some covering. God has, therefore, ordained that the rain, which in summer cools and revives the plants, should, in winter, fall in the form of a soft wool to cover the vegetables, and to guard them from the inclemency of frosts and winds. It prevents the internal heat of the earth from escaping,

and forms a safe covering to the tender herb, till the winter cold has abated under the influence of the genial spring.

5. *Hail.*—Hail, which is a more compact mass of frozen water than snow, is formed by the congelation of vapour in the higher regions of the atmosphere. The drops of hail assume various figures, being sometimes round, at other times pyramidal, angular, thin, and flat, and sometimes stellated with six radii, like the small crystals of snow. When hailstones are broken open, or cut across, they are sometimes found within to be of a spongy structure; sometimes the interior presents a very beautiful radiated appearance, and not unfrequently exhibits regular and very remarkable concentric plates. They are often of considerable dimensions. They vary in size from that of a small seed, to that of a boy's marble; and, in some instances, they have been found as large as the eggs of a goose; the small generally falling in the more northerly climates, and on the tops of mountains, and the larger in France, Spain, Italy, and other countries, towards the south of Europe. Hailstones have fallen in Scotland, which have been proved to weigh five ounces. In North America, they have sometimes been picked up weighing fifteen ounces; and, on October 5th, 1831, one fell at Constantinople which weighed more than a pound! The average velocity with which they fall, has been estimated at seventy feet per second, or at *the rate* of fifty miles an hour; and conse-

quently, their great momentum, arising from this velocity, frequently renders them very destructive, particularly in hot climates. They beat down the crops, strip trees of their leaves, fruits, and branches, and sometimes kill even large beasts and men. A few years ago, a tremendous storm happened in Gloucestershire, accompanied with a most remarkable hail-shower. The masses of ice which fell in places where the storm most fiercely raged, bore no resemblance to the usual state of hailstones in magnitude or *formation*, most of them being of a very irregular shape, broad, flat, and ragged, and many of them measuring nine inches in circumference. They appeared like fragments of a vast plate of ice, broken into small masses, by its descent towards the earth.

6. *Dew.*—Dew is vapour condensed into visible drops. It begins to be deposited about sunset, and is most abundant in valleys and plains near rivers and other collections of water, and abounds on those parts of the surface which are clothed with vegetation. In this island, the dew is observed, like the drops of drizzling rain, upon the leaves of grass and other vegetables, upon wood, glass, porcelain, etc., or upon the earth, which is thereby rendered sensibly moist. It falls more copiously in spring and summer than at any other times of the year. In countries situated near the equator, the dews are generally observed in the morning throughout the year; and in some places in the east, where rain seldom falls,

they are so copious, as, in a great measure, to supply its deficiency. During the heat of the day, a great quantity of vapour is thrown into the atmosphere from the surface of the earth and waters. When the evening returns, if the vapour has not been carried off by currents, it will happen that more remains diffused in the general atmosphere than the temperature of the night will permit to subsist. A decomposition of the aqueous atmosphere then commences, and is continued till the general temperature and aqueous pressure arrive at an equilibrium, or till the returning sun puts an end to the process.

Hoar-frost, which appears like a powdery crystallization on trees and herbage, is only frozen dew. The conversion of dew into hoar-frost is another wise arrangement of nature by which plants are protected from the severity of a freezing cold atmosphere. *Fogs* are clouds which float on the surface of the earth, and clouds are fogs in the higher regions of the atmosphere. From many elevated places they may be seen moving in the valleys, and from the valleys they may frequently be seen creeping along the sides of the mountains.

CHAPTER II.

Winds.

1. WINDS *in general.*—Wind is the motion of a body of air flowing from one place to another. The earth being surrounded by a fine invisible fluid, extending several miles above its surface, is acted upon by heat and cold arising from different causes. This appears to be the general cause of the phenomena of winds; and, according to the force or velocity with which the masses of air move, we use the terms, a breeze, a gale, a storm, a tornado, a whirlwind, a hurricane, etc. When a fire is made in the open air, the rarefied part of that fluid will ascend in a current, and the cooler and denser air will rush in on all sides, in consequence of which a wind is generated, and blows constantly towards the fire. The wind thus produced will be too inconsiderable to be perceived at any great distance, but the rarefaction which arises from natural causes may be such as to agitate our atmosphere sufficiently to produce those torrents of air which have always a powerful effect in nature, and which

sometimes overwhelm and destroy the fairest and most superb productions of human art. Among the causes which produce this rarefaction of the atmosphere, and generate wind, the heat of the sun is not the least powerful. When the solar rays, by their reflection from the earth's surface, have heated or rarefied a portion of the surrounding air, the air so rarefied ascends into the higher regions of the atmosphere, and the colder air, by which it was surrounded, moves forward in a sensible current to fill the vacuity. Likewise, when a condensation of vapour in the atmosphere suddenly takes place, giving rise to clouds which speedily dissolve in rain, the temperature of the surrounding air is sensibly altered, and the colder rushing in upon the warmer, gives rise to a sudden gust of wind. In regard to the particular causes which produce the various winds which prevail in different regions of the globe, different opinions have been entertained by philosophers. And, therefore, instead of examining theories and doubtful opinions on this subject, the writer will confine himself to the statement of a few facts respecting the different species of winds as they are found to operate in different countries.

2. *General, or permanent winds.*—Winds are commonly divided into three classes, namely, general, periodical, and variable winds. General winds are those which are permanent, and blow always in the same direction, and have *received the* name of trade-winds. These winds

prevail chiefly within the tropics, and a few degrees beyond. On the north of the equator, their direction is from the north-east, varying at times a point or two of the compass each way. On the south of the equator, they proceed from the south-east. These winds constantly range in one direction, but never extend further than 30° from the equinoctial, either north or south. In the Atlantic and Pacific oceans, under the equator, the wind is almost always easterly; more to the northward, it generally blows between the north and east; and, more to the southward of the equator, it blows between the south and east. The origin of these winds appears to be as follows:—the powerful heat of the torrid zone rarefies the air of that region; in consequence of this rarefaction, the air rises, and, to supply its place, a colder body of air from each of the temperate zones moves towards the equator. But these north and south winds pass from regions where the rotatory motion of the earth's surface is less to those where it is greater. Unable at once to acquire this new velocity, they are left behind; and, instead of being north and south winds, as they would be if the earth's surface did not turn round, they become north-east and south-east winds.

3. *Periodical winds, or monsoons.*—Those winds, which blow in a certain direction for a time, and at certain stated seasons, change, and blow for an equal space of time from the opposite point of the compass, are called *monsoons*.

During the months of April, May, June, July, August, and September, the wind blows from the southward or south-eastward over the whole length of the Indian ocean, namely, between the parallels of 28° north and 28° south latitude, and between the eastern coast of Africa, and the meridian that passes through the western part of Japan; but, in the other months, October, November, December, January, February, and March, the winds in all the parts of the Indian ocean shift round, and blow directly contrary to the course they held in the former six months. These winds suffer partial changes in particular places, owing to the form and position of the lands, and other circumstances. When they shift, or when the south-west monsoon is about to commence, it is ushered in by vast masses of clouds from the Indian ocean, accompanied with violent blasts of wind, which are succeeded by floods of rain, during which, the lightnings flash without intermission, and the thunders roll with loud and deafening peals; and, when it ceases, the rain pours down in large volumes. This terrific commotion of the elements lasts for many days.

4. *Land and sea breezes.*—These are another kind of periodical winds which are common on the coasts and islands situated between the tropics. During the day, the wind blows for a certain number of hours from the sea to the land; but, when evening arrives, it changes its direction, and blows as many hours from the *land to the* sea. The cause of these alternations

appears to be as follows:—water, being a better conductor of heat than earth, is always of a more even temperature. During the day, therefore, the land becomes considerably heated, the air rarefied, and, consequently, in the afternoon, a breeze sets in from the sea, which is less heated at that time than the land. On the other hand, during the night, the earth loses its surplus heat, while the sea continues more even in its temperature. Towards morning, therefore, a breeze regularly proceeds from the land towards the ocean, where the air is warmer, and, consequently, more rarefied than on the shore.

5. *Variable winds.*—In most countries to the north and south of the tropics, the winds are very irregular and uncertain, and vary in their direction at certain seasons of the year. In Germany, the east wind is most frequent at Gottingen, Munich, Weissemburg, Dusseldorf, Erford, and Buda; the south-east, at Prague and Wirtzburg; the north-east, at Ratisbone; and the west, at Manheim and Berlin. Along the whole south-west of France, the wind blows most frequently from the north, north-west, and north-east; on the west coast, from the west, north-west, and south; and, on the north coast, from the south-west. In Great Britain, the north-east and south-west winds most frequently prevail, along with occasional north-west and south-east winds. From ten years' registers kept by the Royal Society, it appears that, in London, the winds blow in the following order:

from the south-west, 112 days; north-east, 58; north-west, 50; west, 53; south-east, 32; east, 26; south, 18; north, 16. From the same register, it appears that the south-west wind blows at an average more frequently than any other wind during every month of the year; that the north-east blows most constantly during January, March, April, May, and June, and that the north-west wind blows oftener from November to March, and more seldom during September and October than any other months. In Scotland, the south-west is by far the most frequent wind over all the country, especially on the west coast. At Edinburgh, the westerly winds have been found to blow 230 days, and the easterly 135. At Saltcoats, in Ayrshire, the south-west wind blows three-fourths of the year, and along the whole coast of Murray, on the north-east side of Scotland, it blows for two-thirds of the year. East winds are common over all Britain, during April and May, but their influence is felt most severely on the eastern coast.

In our northern region, winds seldom excite much alarm, nor are they often attended with the disastrous results which are frequent in the tropical regions. It has, however, sometimes happened, even in England, that winds have produced the most appalling and destructive effects. In the great storm which happened on the 27th December, 1703, the extraordinary power of the wind created a *noise hoarse* and dreadful, like thunder, which

appalled every heart. Horror and confusion seized upon all, whether on land or at sea. One hundred and twenty-three persons were killed by the falling of dwellings, among whom were the bishop of Bath and his lady, by the fall of the episcopal palace. Eight thousand perished in the Severn and the Thames, and in ships blown away, and never heard of afterwards. Land, houses, churches, corn, trees, rivers—all were damaged by its fury. Small buildings were swept away as chaff before the whirlwind; above 800 dwelling-houses were laid in ruins; 2000 stacks of chimneys were blown down in London; 15,000 sheep were destroyed on the banks of the Severn, and 20,000 in the county of Kent; 300 ships, 500 wherries, 300 ship-boats, and 100 lighters and barges, were entirely lost. The Eddystone Lighthouse was precipitated in the surrounding ocean, along with its ingenious architect and those that were with him. The damage done in the city of London alone, by this storm, was computed at above two millions of pounds sterling! Such are some of the dreadful effects of that invisible fluid which surrounds us, when put in rapid motion by the force of currents. Light as its particles seem to be, no human wisdom or power can, in such cases, avert its force, or withstand its dreadful and destructive agency, in allusion to which the Almighty is represented as riding "on the wings of the wind," and directing "the whirlwind and the storm."

6. *Noxious and poisonous winds.*—These

winds prevail most generally in southern climes. Of these, the harmattan is a very singular wind, which blows periodically from the interior parts of Africa towards the Atlantic ocean. The season in which it prevails is, during the months of December, January, and February. It comes on at any hour of the day, and continues five or six days; and there are generally three or four returns of it every season. This wind is distinguished by a fog or haze, and extreme dryness; no dew falls during its continuance, vegetables wither, and the grass becomes dry like hay. The dryness is so extreme, that the covers of books, though closely shut up in a trunk, are bent as if exposed to the fire. Household furniture is damaged, panels of wainscots split, and veneered work flies to pieces. The human body, likewise, feels the parching effects of the harmattan; the eyes, nostrils, lips, and palate, are rendered dry and uneasy; the lips and nose are inflamed, and there is a troublesome sensation of pricking heat on the skin. If the harmattan continue, the scarf-skin peels off, first from the hands and feet, and afterwards from the rest of the body.

The sirocco is a wind which resembles, in some of its effects, the harmattan. It sometimes blows for several days together, and its medium heat is calculated at 112°; it is fatal to vegetation, and destructive to mankind, especially to those who are not natives of the country; it depresses the spirits in an unusual degree; it suspends the powers of digestion in

such a manner that those who venture to eat a heavy supper generally die during the night. The sick frequently sink under the pressure of their diseases, so that it is customary, in the morning after this wind has continued a whole night, to inquire who is dead. During the continuance of this wind, all nature appears to languish, vegetation withers and dies, the beasts of the field droop; the animal spirits are too much exhausted to admit of the least bodily exertion, and the spring and elasticity of the air appear to be lost. In the city of Palermo, in Sicily, where it frequently prevails, the inhabitants shut their doors and windows to exclude the air; where there are no window-shutters, wet blankets are hung on the inside of the windows, and the servants are kept continually employed in sprinkling the apartments with water, and the streets and avenues of the city appear at such times to be nearly deserted. This wind is frequently felt in Greece, Italy, the Levant, and other parts of southern Europe; it is occasioned by currents of heated air from the deserts of Zahara in Africa; but happily it is not of long continuance. In Sicily, it seldom lasts longer than thirty-six or forty hours.

The samiel, or mortifying wind, is perhaps, beyond all others, dreadful in its effects. It generally blows on the southern coasts of Arabia, and the deserts near the city of Bagdad; and is supposed to have been the pestilence of the ancients, frequently killing all those who are involved in its passage. What its malignity

consists in, none can tell, as no one has ever survived its effects to give information. It has been said that it frequently assumes a visible form, and darts in a kind of bluish vapour along the surface of the country. The natives of Persia and Arabia talk of its effects with terror; they describe it as under the conduct of a minister of vengeance, who governs its terrors, and raises or depresses it as he thinks proper. The camels, either by instinct or experience, have notice of its approach, and are so well aware of it, that they are said to make an unusual noise, and cover their noses in the sand. It blows over the desert in the months of July and August, and rushes with violence to the very gates of Bagdad, but never injures any person in the city. To escape its effects, travellers throw themselves as close as possible to the ground, and wait till it has passed by, which is commonly a few minutes. As soon as they who have life dare to rise up, they examine how it fares with their companions by pulling at their arms or legs; for, if they are destroyed by the wind, their limbs are absolutely mortified, and will come asunder. An extraordinary blasting wind is felt occasionally at Falkland's Islands, but it seldom continues above twenty-four hours. It cuts the herbage down as if fires had been made under it, so that the leaves are parched up and crumbled into dust. Fowls are seized with cramp, so as never to recover; and men are oppressed with a stopped perspiration, heaviness at the breast, and sore throats.

The simoon is a hot wind which prevails in Egypt, Arabia, Syria, and the adjacent countries. When it begins to blow in Arabia, the atmosphere assumes an alarming aspect. The sky becomes dark and heavy, the sun loses his splendour, and becomes of a violet colour, and the air is thick from the subtle dust with which it is loaded. At first, the wind is light and rapid, and not remarkably hot; its temperature, however, soon increases, till it ranges at upwards of 128°. When it occurs, all animated bodies discover it by the change it produces in them. The lungs are contracted and become painful, respiration is short and difficult, the skin parched and dry, and the body consumed by an internal heat. The streets are deserted, and the dead silence of night reigns everywhere. The inhabitants of towns and villages shut themselves up in their houses, and those of the desert in their tents, or in wells dug in the earth, where they wait the termination of this destructive heat. The only refuge travellers have from it is, to fall down with their faces close to the ground, and to continue as long as possible without drawing in their breath. Mr. Bruce thus describes it, in his journey through the desert:—"At eleven o'clock, while we contemplated the top of Chiggre, where we were to solace ourselves with water, Idris, our guide, cried out with a loud voice, 'Fall upon your faces, for here is the simoom.' I saw from the south-east a haze, in colour like the purple part of the

rainbow, which did not occupy twenty yards in breadth, about twelve feet from the ground, and it moved very rapidly, for I could scarce turn to fall upon the ground, with my head to the north, when I felt the heat of its current plainly on my face. We all lay flat on the ground as if dead, till Idris told us it was blown over. The meteor or purple haze which I saw was indeed passed, but the light air which still blew was of heat to threaten suffocation. For my part, I found distinctly in my breast that I had imbibed a part of it, nor was I free of an asthmatic affection till I was in Italy two years afterwards."

Hurricanes are violent tempests of wind, accompanied with thunders and lightnings, rain, or hail. These fearful concussions of the atmosphere happen most frequently in the range of the West India Islands, and about the Cape of Good Hope. The forerunner of these hurricanes, when first seen, is only like a small black spot on the verge of the horizon, called by sailors the bull's eye. All this time a perfect calm reigns over sea and land, while at length, coming to the place where its fury is to fall, it invests the whole horizon with darkness. During its approach, a hollow murmur is heard in the cavities of the mountains, and animals, sensible of its approach, run over the fields to seek for shelter. Nothing can be more terrible than its violence when it begins. The sun, *which,* but a moment before, blazed in meridian *splendour, is* totally shut out, and a midnight

darkness prevails, except that the air is incessantly illuminated with gleams of lightning, so vivid that one can see to read, and the rain pours down in torrents. All the elements seem to arm themselves for the destruction of human labours, and even of the scenes of nature herself. The velocity of the wind is such, that corn, vines, sugar-canes, forests, houses, boats, ships, are swept away, or buried in the deep.

A tornado is a sudden and violent gust of wind from all points of the compass. It partakes somewhat of the nature of a hurricane, but is still more violent in its effects. The winds seem to blow from every quarter, and settle upon one destined place, with such fury that nothing can resist their vehemence. When they have met in their central spot, the whirlwind begins with circular rapidity. The sphere every moment widens, as it continues to turn, and catches every object that lies within its attraction. The mariner, within the reach of its influence at sea, must try all his power and skill to avoid it, which if he fail o doing, there is the greatest danger of his going to the bottom. Tornadoes most frequently rage along the coasts of Guinea, and other parts of western Africa.

Such are a few brief sketches of the phenomena of noxious and stormy winds. It is evident that they did not exist in the primitive state of our globe; for the operation of such agents of terror and destruction appears altogether inconsistent with the idea that man is

at present in a paradisaical state, and possessed of that innocence and moral purity in which he was created. It appears incompatible with the idea of an Almighty Intelligence, possessed of boundless benevolence, that innocent beings should be so frequently subjected to the influence of such dreadful agents, by which they are swept from the living world in a manner so appalling and terrific. Man is, therefore, a creature who has fallen from his primitive state of integrity; and such fearful agents, and many others, as the volcano and the earthquake, are so many proofs and evidences of the depravity and fallen state of the human race; otherwise they would not be permitted to inhabit a world where so many destructive influences are in operation. An important change appears to have taken place in the constitution of the atmosphere at the period of the universal deluge, which probably may have given rise to many of the physical evils connected with this part of our terrestrial system; which may, in after ages, be in a great measure removed, when the earth shall be cultivated throughout its whole extent, and universal peace and brotherhood prevail among all nations. Notwithstanding, however, the occasional operation of the destructive agents to which we allude, the arrangements connected with our globe, in their prominent bearings, and considered as a whole, evidently display the long-suffering, the tender mercy, and the goodness of Jehovah, and *should* lead us to humble ourselves in his pre-

sence, under a sense of our manifold deviations from the path of his commandments.

The velocity of winds varies, from the gentlest breeze or an imperceptible movement, to a hundred miles an hour. Light airs may be considered as moving at the rate of from one to three miles an hour, or from a foot and a half, to four feet and two-fifths, per second; a breeze, from four to six miles an hour; a brisk gale, from ten to sixteen miles an hour; a fresh gale, from twenty to twenty-five miles; a strong gale, from thirty to thirty-five miles; a hard gale, from forty to forty-five miles; a storm or tempest, fifty miles; a great storm, sixty miles; a hurricane, eighty miles; a violent hurricane, tearing up trees, throwing down houses, etc., moves at the rate of one hundred miles an hour.

Notwithstanding the occasional ravages of winds, they produce many beneficial effects in the system of nature. They serve as ventilators for purifying the atmosphere; they dispel fogs and noxious vapours; they agitate the waters of the ocean, and prevent them from stagnation and putrefaction; in the heat of summer they fan us with gales and gentle breezes. By their mechanical force, windmills and other machinery are set in motion, and ships impelled across seas and oceans to the remotest corners of the globe, to promote commerce, learning, religion, and the mutual intercourse of human beings.

CHAPTER III.

Luminous and fiery meteors.

1. *The aurora borealis.*—This is one of the most splendid phenomena which appears in the visible sky, especially when its coruscations diffuse themselves over the whole face of the heavens. The appearances of the aurora may be arranged under the following particulars:—1. A horizontal light, like the morning twilight or break of day. This light generally appears in the north or north by west, and sometimes seems as if it broke out from a few darkish clouds. 2. Fine, slender, luminous beams, well defined, and of a dense light. These frequently continue a half or a whole minute apparently at rest, but more frequently with a quick lateral motion, that is, from east to west, or the contrary. 3. Flashes pointing upwards, or in the same direction with the beams, which they always succeed. These are only momentary, and have no lateral motion, but they are generally repeated many times in a minute. They appear much broader, more diffuse, and of a weaker light than the beams; they grow gradu*ally fainter* till they disappear, and sometimes

continue for several hours, flashing at intervals. Sometimes they are confined chiefly to the northern region of the heavens, and at other times illuminate the whole sky with their fantastic coruscations. Such are some of the general appearances of the aurora borealis, but they are strikingly varied at different times, and it is difficult accurately to describe the shifting and splendid phenomena they present.

The aurora has been occasionally seen in all ages: it is spoken of by Herodotus, Xenophon, Diodorus Siculus, Homer, Virgil, and Ossian, the Highland bard. Aristotle, in his work on meteors, describes it as "an appearance observed by night in calm weather, resembling flame mingled with smoke, or the distant appearance of burning stubble; the predominant colours being purple, bright red, and blood colour." It has been more frequently observed in this country since the year 1716, when, on the 6th of March, it appeared with a splendour which attracted universal attention, and was considered by many as prognostic of wars, famine and pestilence, and a foreign race of princes.

The following is a description of an aurora, as seen by Dr. Dalton:—"Attention was first excited by the remarkably red appearance of the clouds to the south, which afforded sufficient light to read by at eight o'clock in the evening, though there was no moonlight in the north. From half-past nine to ten, P.M., there was a large luminous horizontal arch to

the southward, and one or more concentric arches northward. At half-past ten o'clock, streamers appeared very low in the south-east, running to and fro from west to south; they increased in number, and began to approach the zenith apparently with an accelerated velocity, when all of a sudden the whole hemisphere was covered with them, and exhibited such an appearance as surpasses all description. The intensity of the light, the prodigious number and velocity of the beams, the grand intermixture of all the primitive colours in their utmost splendour, variegating the glowing canopy with the most enchanting scenery, afforded an awful, but, at the same time, pleasing and most sublime spectacle. Every one gazed with astonishment, but the uncommon grandeur of the scene only lasted one minute; the variety of colours disappeared, and the beams were converted into the flashing radiations; but even then it surpassed all other appearances of the aurora; in short, the whole hemisphere was covered with it."

The writer had occasion to witness a splendid and somewhat terrific display of this phenomenon, in the vicinity of Dundee, on the 17th November, 1835. A little before nine o'clock, P.M., the coruscations first began to appear, which, in a short time, diffused all the brightness which appears in a moonlight evening. About ten o'clock, the aurora shone in all its splendour, when coruscations, or streams of light, more *than thirty* or forty degrees in length, appeared

to issue from a central point near the zenith, and to extend themselves in every direction, south, north, east, and west, like the meridians on an artificial globe. The most singular feature displayed by this aurora was that of a number of streams of light of a dark red colour, like blood, and resembling expansive sheets of flame, which were seen in all directions mingling their streams with the more brilliant yellow coruscations, and giving to the whole celestial concave an appearance of terrific grandeur, which seemed to impress the mind of every beholder with awe and terror. This display continued during the night till four o'clock next morning, and was visible over the whole island of Great Britain. In London, it produced such an effect, that the policemen, ignorant of its nature, hurried to and fro through all the avenues of that city in search of fires, which they imagined had burst forth from every quarter. On the evening of September 29, 1847, about ten o'clock, a brilliant and rather uncommon aurora made its appearance, near Dundee. The sky was strongly illuminated in the north, and numbers of spiral coruscations shot upwards towards the zenith. But its most striking peculiarity was that, on a sudden, and in a portion of the sky which was perfectly clear, an immense stream of light began to blaze with a quivering motion, like a huge serpent, or in a form like the letter s, extending forty or fifty degrees in length, and several degrees in breadth. Such streams of brilliant

light, which appeared and vanished with all the rapidity of lightning, were to be seen over most regions of the sky.

This phenomenon appears more frequently, and displays itself in still greater splendour in the polar regions than in our country. It is also said that, in those regions, a hissing sound is heard during its continuance. During the long nights of winter in those countries, particularly in Lapland and Greenland, its radiations, along with the light of the heavenly bodies, are sufficient to guide the inhabitants in their journeys, and to enable them to engage in all the other avocations of life. In the northern parts of Siberia, the aurora begins with single bright pillars rising in the north, which, gradually increasing, comprehend a large space in the heavens, rush about from place to place with incredible velocity, and at last cover almost the whole sky up to the zenith, and produce an appearance as if a vast tent were expanded in the heavens glittering with gold, rubies, and sapphires. It has been found, likewise, that these brilliant phenomena are visible in the south polar regions as well as in the north.

Various opinions have been formed as to the cause which produces the phenomena of the aurora. Most philosophers seem to agree that it is of an electrical nature, as its appearance can be imitated by artificial electricity. Dr. Faraday considers it as highly probable, "that *it is a* luminous accumulation of electricity

flowing from the equator to the poles, for the restoration of electric equilibrium." But whatever may be the physical cause of the aurora, it presents to our view one of the most beautiful, sublime, and at the same time awful and mysterious phenomena which appear in our sky—while its coruscations sometimes cover, with inconceivable magnificence, the concave of the whole hemisphere, changing their positions every moment, now resembling vast pyramids, or innumerable columns, now vanishing in a moment, leaving the heavens sombre and black, and now returning with increased splendour, shedding a matchless glory over the heavens. Such striking phenomena evidently display the majesty and glory of the Creator and his power to cause the invisible elements of nature to produce the most grand and diversified scenery—and although their mode of operation is not thoroughly discovered, they are, doubtless, intended to subserve beneficial purposes in the system of creation.

2. *Luminous arches.*—These are somewhat striking phenomena, which sometimes precede, or accompany the aurora borealis, but they make their appearance only at very distant intervals. The writer has seen only four or five of these arches within the space of the last thirty years. One of the most brilliant of the arches appeared on the 27th August, 1846, and was first perceived a few minutes before nine o'clock in the evening. It was a grand and beautiful luminous arch, which stretched from

one side of the heavens to the other, forming a most resplendent object in a clear and serene sky. Its highest point was about seventy-five degrees above the southern horizon—a little above the brilliant star, Vega Lyra. Like all the other arches of this kind he has seen, it had a gradual motion downward towards the southern horizon, so that in the course of twenty minutes it was considerably below the star now mentioned. Its direction was from east by north, to west by south, or nearly at right angles with the magnetic meridian—which seems to indicate that it is connected with the operation of the magnetic principle. This is the exact direction of all the luminous arches now referred to, and they are all evidently connected with the appearance of the aurora borealis, and may be considered as a peculiar modification of this phenomenon. Its breadth was greater than that of a common rainbow; there appeared no prismatic colours, but a pure brilliant white, contrasting most beautifully with the deep azure of the sky. An aurora appeared at the same time in the north and north-west, but its coruscations were not very vivid, and continued only for a very short time. The arch began first gradually to disappear at its extremities, near the eastern and western horizon, and, about forty minutes after having been first seen, it was completely dissipated. The height of such phenomena above the earth has been variously estimated. Euler estimated them at *1,000 miles*; Boscovich, at about 800; Bergman,

at 460; and Dr. Dalton, at 150 miles, which is perhaps nearest the truth. Whatever may be the height of the luminous arches, we have reason to believe that the elevation of the aurora borealis above the earth is the same, as they evidently are produced by the operation of the same cause.

3. *Fire-balls.*—These are a species of luminous or fiery bodies which are occasionally seen to wing their flight through the upper regions, with a considerable degree of velocity and splendour. In tropical climates, these bodies are more frequently seen than in our more temperate regions. The following are a few brief descriptions of some of the meteors. Mr. Barham relates that, when he was riding in Jamaica, one evening, he beheld a ball of fire apparently about the bigness of a bomb, swiftly falling down with a great blaze. Approaching the place where it fell, he found the ground strangely broken up and ploughed, and several holes appeared of the bigness of a man's head, and all the green herbage burned up near the holes; at the same time, a strong smell of sulphur. In the year 1676, a great globe of fire was seen at Bononia, in Italy, about forty minutes after sunset. It passed with a most rapid course, and at the rate of not less than one hundred and sixty miles a minute, and at last stood over the Adriatic sea. It crossed all Italy in its course, and, by computation, it was found that it could not have been less than thirty-eight miles above the surface of the

earth. Wherever it approached, the inhabitants below could distinctly hear it with a hissing noise, resembling that of a firework. It was heard to go off with a violent explosion. Its magnitude, when at Bononia, appeared twice as long as the moon, one way, and about as broad the other. It was estimated to be a mile long and half a mile broad.

One of the most striking and extraordinary meteors of this kind made its appearance on the 18th August, 1783, about nine o'clock in the evening. It was seen in all parts of Great Britain, from the Shetland isles to the English channel, over all France, and the greatest part of Italy, and is supposed to have described a tract of at least one thousand miles over the surface of the earth. It appears to have burst and re-united several times, and the first bursting which was noticed was somewhere over Lincolnshire, in England. Its appearance produced universal wonder and alarm. When it was observed at Brussels, the moon appeared quite red, and the illumination was so great as totally to obliterate the stars. A report was heard sometime after it disappeared, which was loudest in Lincolnshire, and afterwards in the eastern parts of Kent. A hissing sound was said also to accompany its progress. At Greenwich, two bright balls, parallel to each other, led the way, and were followed by an expulsion of eight others. The balls were tinted first with a pure bright light, then followed a yellow mixed *with azure*, red, and green, which, with a

coalition of bolder tints, and a reflection from the other balls, gave the most beautiful rotundity and variation of colour with which the human eye could be charmed. The height of this fire-ball was reckoned at from seventy to ninety miles, its diameter was estimated at nearly two miles, and its velocity at about 1,000 miles a minute.

As to the physical causes which produce these extraordinary meteors, we are still in a great measure ignorant. The general opinion among philosophers is, that they owe their origin to the operation of electricity. The velocity with which these meteors wing their flight — the electrical phenomena attending them, the lambent flames and sparks proceeding from them — their connexion with the aurora borealis, on whose appearance luminous balls have been seen formed and darting about with great velocity—and their general motions, which are constantly from or towards the north or north-west— have been viewed as so many arguments corroborative of their electrical origin. Still it is difficult to account for all the phenomena exhibited by these bodies by electricity alone, since some of these bodies appeared to be of a denser and more compact structure than electricity could produce.

4. *Shooting or falling stars.* — These are meteors which are frequently seen darting through the sky, in the form of stars, and most frequently accompanied with a train of light. The nature of these bodies has not yet been

well ascertained, and philosophers have of late been disposed to alter their former opinions respecting them. It appears, from certain late observations made at Breslau by professor Brandes and his pupils, that the height of some shooting-stars is not less than five hundred miles, and that they move at the rate of eighteen miles in a second. A most extraordinary and wonderful display of the phenomena of shooting-stars has of late occurred in different places, particularly in America. On the evening of the 12th and the morning of the 13th November, 1833, a shower of these meteors happened at Boston, New York, and other places, and their number was considered to equal one-half of the flakes which fill the air in an ordinary fall of snow. It was calculated that, in some places, they fell at the rate of 36,000 per hour, and the phenomena lasted more than seven hours. At Boston, the number of shooting-stars which were seen was estimated at two hundred and forty thousand. Similar phenomena, though not in such numbers, have appeared in various other places, and in the subsequent years, from the 12th to the 15th November, and hence they have been denominated the November meteors. M. Arago, the French philosopher, is of opinion, that such extraordinary phenomena cannot well be accounted for, unless it be supposed that, besides the planetary bodies which revolve around the sun, there are myriads of smaller bodies, which *only* become visible at the moment when they

come within our atmosphere and assume a meteoric appearance; and that they move in groups, and also singly. Dr. Olmsted, of Newhaven, who particularly investigated the meteoric showers of 1833, deduces the following among other conclusions:—That the distance of the body whence they emanated was about 2,238 miles—that they entered the earth's atmosphere with a velocity of four miles per second—that some of the larger meteors must have been bodies of great size, not less than a mile in diameter—and, that they consisted of portions of a nebulous body which revolves around the sun, in one hundred and eighty-two days.

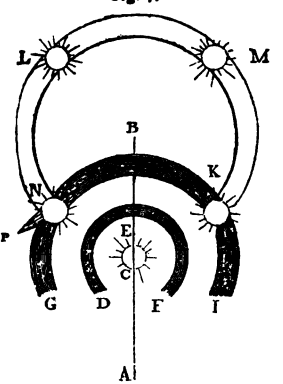
We may learn from such phenomena that, if the universe were not under the superintendence of a wise and benevolent Being, or if the powers of nature were left to act at random, the world in which we live might be subjected to manifold disasters from unknown bodies and unseen causes, from which we have hitherto been protected.

5. *Parhelia, or mock-suns.*—A parhelion is a meteor in the form of a very bright light appearing on one side of the sun, and resembling that luminary. They generally seem about the size of the true sun, not quite so bright, though sometimes they are said to rival their parent luminary in splendour. When there is a number of them, they are not equal to each other in brightness, and externally they are tinged with colours like the rainbow.

They differ in number and size; but they all agree in breadth, which is that of the apparent diameter of the sun.

The phenomena of these meteors observed by Scheiner, at Rome, is represented at fig. 21, in which A is the place of the observer; B, his zenith; C, the true sun; AB, a plane passing through the

Fig. 7.



observer's eye, the true sun, and the zenith. About the sun, C, there appeared two concentric rings, not complete, but diversified with colours. The lesser of them, DEF, was fuller and more perfect; and though it was open from D to F, yet those ends were perpetually endeavouring to unite, and sometimes they did so. The *outer of* these rings was much fainter, so as to

be scarcely perceptible. It had, however, a variety of colours, but was very inconstant. The third circle was very large, and entirely white, passing through the middle of the sun, and everywhere parallel to the horizon. In the intersection of this circle, and the outward iris, GKI, there broke out two parhelia, N and K. The brightness of the middle of them was something like that of the sun, but towards the edges they were tinged with colours like the rainbow. The parhelion N was a little wavering, and sent out a spiked tail, NP, of a colour somewhat fiery. The parhelia at L and M were not so bright as the former, but were rounder and white, like the circle in which they were placed. The parhelion N disappeared before K, and while M grew fainter, K grew brighter, and vanished the last of all. Parhelia have been visible for two, three, and four hours together, and in North America they are said to continue some days, and to be visible from sunrise to sunset.

6. *Thunder and lightning.*—These sublime and terrific phenomena are well known to every individual, and are occasionally displayed in every region of the globe. A thunder-storm usually happens in calm weather, though sometimes it has been accompanied with furious winds. A dark cloud is observed to attract other clouds to it, by which it continually increases both in magnitude and apparent density; and when it has thus accumulated to a great size, its lower surface swells in particular

parts towards the earth, and light flimsy clouds are sometimes seen flying under it, and continually changing their ragged shape. During the time the cloud is thus forming, the heavens begin to darken apace, the whole mass sinks down, wind arises, and frequently shifts in squalls, flashes of lightning are seen to dart from one part of it to another, and often to illuminate the whole mass and the surrounding landscape. When the cloud has acquired a sufficient expansion, the lightning strikes the earth in two opposite points; its paths lying through the whole body of the cloud. Heavy rains, and sometimes hail-showers, accompany these dire phenomena, till, after numerous successive discharges, the cloud rarefies, and the storm ceases. The scene of a thunder-storm is generally in the middle regions of the atmosphere; and it is not a frequent case that an electrical discharge is made into the earth. The lightning darts from one cloud into another, and when the clouds are high, there is no danger to persons or objects on the surface of the earth. But when the cloud is low, and within the striking distance of the earth, when the flashes appear to strike perpendicularly, and when only a second or two elapse between seeing the flash, and hearing the report of the thunder, every object around may be considered as within the limits of danger; for then the lightning strikes into some part of the earth, and every object in the line of its course is *liable to* be injured. We may ascertain the

distance of a thunder-cloud, by counting the number of seconds or pulsations that intervene between seeing the lightning, and hearing the first sound of the thunder, allowing about 1,142 feet, or 380 yards for every second. Thus, if two seconds intervene, the distance is 760 yards; if three seconds, 1,140 yards; if four and a half seconds, 1,710 yards, or nearly a mile, etc. During a thunder-storm, the lightning sometimes assumes different forms. Sometimes it appears as balls of fire, moving with great velocity: this is the most dangerous species of lightning, and where they strike, corn-yards are set on fire, and sometimes flocks of sheep, herds of cattle, and human beings, are instantly killed. Another form is that of zig-zag lightning, which most frequently accompanies thunder-storms. It is likewise destructive, but not to the same extent as the ball-lightning. The next species is the sheet-lightning, which appears in the form of a lambent flame, or a sudden illumination, without any determinate form. It is never known to do any injury.

As to the cause of thunder-storms, it is now ascertained, beyond dispute, that lightning and electricity are identical. This had been, long ago, surmised, after the attention of philosophers had been directed to the subject of electricity. It was observed that lightning, in its course, took the best conductors of electricity, such as bell-wires, and gildings; that it burned, exploded, and destroyed conducting substances, as electricity does; that it struck the most

elevated objects, as trees and spires; that the crooked form of zig-zag lightning was similar to that of an electric spark; and that it affected the nervous system, and changed the polarity of the mariner's needle, as electricity was found to do. This was, at last, put to the test of experiment by Dr. Franklin, by elevating, during a thunder-storm, a kite, with a metallic point on the head of it, when he drew an electric spark from the cloud by means of a key, connected with the wet string, which was connected with the kite.

Maxims during a thunder-storm.—When in the open fields, avoid trees, but be near them—say at the distance of thirty or forty feet—as high objects are more likely to be struck with lightning than those which are low. When walking in the open air, avoid ponds, rivers, streamlets, and every mass of water; for water, being a conductor of electricity, might determine the lightning to the place we occupy. Do not avoid rain, as it is safer, in a thunder-storm, to be completely drenched, than otherwise. When in a house, persons should avoid sitting near the fire-place, as it brings us in connexion with the highest part of the building, and which contains such conducting substances, as the grate, the fender, and fire-irons. Bell-wires, mirrors, gildings, lustres, and other metallic substances, should also be avoided. The safest position is in the middle of a large room, at a distance from conducting substances, with our chair placed on a mattress.

In the preceding pages, we have taken a cursory survey of the nature and properties of the atmosphere, and of the phenomena it frequently presents, and have noticed the evidences of Divine wisdom and beneficence as displayed in the arrangements connected with this admirable appendage to our globe. A devout contemplation of this subject is worthy of the serious attention of every rational and Christian mind; for all the works of God are intended to display to intelligent beings certain parts of the character and attributes of the Almighty, and to inspire us with love and gratitude for those merciful and benevolent arrangements by which our lives are preserved, and our happiness and comforts secured. The system of the material world, in all its varieties, may be considered as one of the revelations given by God to man, in order that we may trace, from his external operations, visible to every eye, something of the nature of that Almighty Being who at first brought all things into existence, and who, every moment, superintends all their movements. Hence we are informed, by an inspired writer, that the "invisible things of Him from the creation of the world are clearly seen, being understood by the things that are made, even his eternal power and Godhead."

Had man continued in primeval innocence, in the complete exercise of his moral and intellectual faculties, this would perhaps, have been the only revelation of which he stood in need.

But, in his present fallen state, the investigation and study of the material world are not sufficient to lead him to the knowledge of the true God, and to guide him in the way that leads to immortal happiness. Hence it happened that even the wisest sages of antiquity, who were destitute of any other revelation, completely failed in attaining to just conceptions of the Eternal Divinity, of the worship and homage he required, of the duties they ought to perform, and of their eternal destination. "Professing themselves to be wise, they became fools, and changed the glory of the uncorruptible God into an image made like to corruptible man, and to birds, and to four-footed beasts, and creeping things."

The religion of nature is glaringly deficient in directing us to correct views of the attributes of the true God, and particularly of the conceptions we ought to form of his moral character, as a Being possessed of strict and impartial justice and eternal rectitude, and whether he be disposed to the exercise of mercy and love. Hence, some of the ancient philosophers denied his existence, and others embraced the notion of a multiplicity of gods, celestial, aërial, terrestrial, and infernal; and the moral characters and actions attributed to such deities were distinguished for everything that was wicked, base, cruel, and licentious. The light of nature can afford us no certain and indubitable evidence of the immortality of *the soul*, a future state of eternal rewards and

punishments, or of a future and glorious resurrection. For many opposite and discordant opinions prevailed on this subject among those who were destitute of Divine revelation; some of them absolutely denying the existence of such a state as a vulgar error; while others represented it as altogether uncertain, having no solid foundation for its support. The light of nature can convey no proper notion of a creative Power that could produce the universe out of nothing, nor of the time and manner in which the world was created and arranged. Hence, one sect of heathen philosophers held that the world was eternal, and another, that it was formed in its present admirable order by a fortuitous concourse of innumerable atoms. It can afford us no certain information respecting the origin of evil, and the cause of that depravity and misery which exist among mankind; and, in short, it can point out no method by which those who have offended God may be certainly restored to his favour, and a reconciliation effected between God and man; so that his mercy may be exercised without the violation of his justice, and the pardon of sinners rendered consistent with the honour of his laws and the wisdom and equity of his government. From nature, therefore, there arises no sufficient comfort to sinners to warrant hopes of forgiveness; but, on the contrary, anxious and endless solicitude about the means of appeasing the Deity. Hence the various modes of sacrificing, and the numberless super-

stitions which overspread the heathen world, but which were unsatisfactory to the wiser part of mankind, even in the times of pagan darkness and ignorance.

While ignorant of the important and interesting truths now adverted to, we can enjoy no solid happiness in the present state, nor any cheering prospects in reference to a future and eternal world. But, on all these subjects, so interesting to every human being, the Christian revelation throws an effulgence of light and evidence, and affords every satisfaction to the anxious mind which it can desire. It has "brought life and immortality to light," and shed a radiance over the mansions of the tomb, and the scenes of a future world; it has unravelled the origin of evil, and the cause of all those miseries and moral abominations which have prevailed in the world; and, above all, it has disclosed the gracious purposes of the God of mercy and love towards our fallen and apostate world, and opened the way by which sinners may be pardoned and restored to the Divine favour, in full consistency with all the perfections of the Divinity, and the honours of his universal government. For thus runs the declaration of the Most High to all the children of man: "God so loved the world that he gave his only-begotten Son, that whosoever believeth in him should not perish, but have everlasting life." He sent his Son into our world, as a messenger of peace, "to bear the sin of many," "*to* bring in everlasting righteousness," to

make "intercession for the transgressors," to vindicate the honours of his broken law, to abolish death, and to open the way to the mansions of glory in the heavens, to men of all nations, kindreds, and languages, who receive the record he hath given of his Son, and submit to the method of salvation he hath devised. He hath set forth his son to the world to be "a propitiation through faith in his blood, to declare his righteousness for the remission of sins, . . . that he might be just and the justifier of him which believeth in Jesus." It is, therefore, "a faithful saying, and worthy of all acceptation, that Christ Jesus came into the world to save sinners," even the chief. And all who receive the salvation thus proffered, will consecrate themselves to his service, and, by the aid of the Holy Spirit, prosecute a course of obedience, "denying ungodliness and worldly lusts," and living "soberly, righteously, and godly in the present world." Every sin and violation of the Divine law will be carefully avoided; every holy disposition, every heavenly temper, and every Divine virtue and grace will be sedulously cultivated; love to God and man will pervade all the faculties of the soul, and be displayed in the general tenor of the conduct; and, by pursuing such a course of action, the individual will be gradually prepared for the nobler contemplations and exercises of that higher sphere of existence, where there is "fulness of joy," and "where there are pleasures for evermore."

From what we have now stated, we fairly conclude, that all our contemplati the works of nature, and all our investig of the system of the visible creation, ou be conducted in connexion with the viev discoveries unfolded by Divine reve The two revelations which God has m us, when properly studied, will be four only in perfect harmony, but to throw a r light on each other; so that what may deficient in the one is supplied by the While we contemplate the manifestati Divine power, wisdom, and goodness, i arrangements and operations of nature, w ceive the same attributes illustrated i records of revelation; and, in addition to we perceive what nature cannot teach u God is a Being of perfect and eternal rec of inviolable faithfulness, of boundless b lence; ready to forgive, and rich in me all who call upon him in truth:—a Bein fills the immensity of space with his pr who possesses the most intimate knowle all creatures and events throughout cr and who superintends all the movements material universe. To whatever scene ture we direct our attention, we find senti in Scripture adequate to express every e of the soul while engaged in such c plations. Are we contemplating the im number and variety of animated beings people the earth, the waters, and the a the ample provision made for their acc

dation and subsistence—where can we find language more appropriate to express our feelings than in these words of the Psalmist, "O Lord, how manifold are thy works, in wisdom hast thou made them all: the earth is full of thy riches. So is this great and wide sea, wherein are things creeping innumerable, both small and great beasts.—These wait all upon thee; that thou mayest give them their meat in due season. That thou givest them—they gather; thou openest thine hand—they are filled with good." When we survey the structure of the human frame, and consider the vast number of bones, muscles, veins, arteries, lacteals, and other parts, all curiously combined, performing such a variety of functions, and all contributing to life and enjoyment—can we refrain from adopting the expressive language of the Psalmist? "I will praise thee; for I am fearfully and wonderfully made: marvellous are thy works!—How precious are thy thoughts unto me, O God! how great is the sum of them! If I should count them they are more in number than the sand." When we consider the amazing structure of the heavens—the immense magnitude and number of the mighty orbs contained within the canopy of the sky—that millions upon millions of suns and worlds stretching into the immensity of space far beyond the limits of our vision, or even of our imagination, form only a small portion of the universal empire of the Almighty; and when the mind is overwhelmed and lost, on the view

of this stupendous scene—where shall we find language to express our emotions, more emphatic and appropriate, than in such passages as these? "Canst thou by searching find out God? Canst thou find out the Almighty unto perfection?—Great is our Lord and of great power: his understanding is infinite;—his greatness is unsearchable.—The heavens declare the glory of God; and the firmament showeth his handywork.—All nations before him are as nothing; and they are counted to him less than nothing, and vanity—which doeth great things past finding out; yea, and wonders without number.—Great and marvellous are thy works, Lord God Almighty. Who can utter the mighty acts of the Lord? Who can show forth all his praise?"

THE RELIGIOUS TRACT SOCIETY, INSTITUTED 1799.